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THE MONTH.

THE WITHAM RAILWAY ACCIDENT.—No definite decision has been arrived at by the coroner's jury as to the cause of this mysterious disaster. The expert witnesses called on behalf of the Great Eastern Railway all testified that the permanent way and rolling stock was in perfect condition, and the only inference left is that the track, at the place where the derailment of the train occurred, could not have been entirely suitable for express traffic. This suggestion is to some extent confirmed by the fact that the locomotive passed the point in question without any mishap. The derailment of vehicles appears to be at the bottom of most railway accidents in the present day, often owing to the maintenance of excessive speed round curves. Light vehicles, such as those employed on the Central London Railway, are especially liable to jump the metals, and only a few days ago one of the new electric trains on the Metropolitan Railway became derailed when entering Moorgate-street station. The whole subject is one clearly demanding the close attention of railway engineers.

THE SCOTCH STEEL TRADE.—Within the last three months a gratifying revival has been evidenced in the steel trade of Scotland, all the leading makers being so full of orders that many of them are no longer in a position to entertain fresh business proposals. The Steel Company of Scotland, in particular, has been remarkably successful in securing foreign Government contracts in competition with American, French, and German rivals. In fact, it is announced that owing to the magnitude of the work so obtained, the company have been reluctantly compelled to refuse further orders to the extent of some 50,000 tons of steel. One reason for the success of this firm is to be found in the superiority of the samples furnished with their tenders, but another of equal importance is that the thorough reorganisation of their manufacturing plant has placed the company in a position to compete on favourable terms with the largest steel-producing associations in the world.

MOTOR BARGES.—We have referred on previous occasions to the advantages of motor boats in connection with the fishing industry of Scotland, and to the regrettable circumstance that the mechanical equipment for such vessels will in all probability be supplied by Continental firms. There is another direction, however, in which British firms ought to prepare themselves for the application of petrol motors. We refer to barges used on canals and in rivers such as the Thames. In Dutch and Belgian ports between 3,000 and 4,000 motor barges

are now in use, and there is no reason why the introduction of similarly equipped vessels on British waterways should be delayed until foreigners begin to exploit the market.

BRITISH ENGINEERS AND EGYPT.—Notwithstanding the predominant interest of the British nation in Egypt, it is with regret that we notice how feeble and ill-directed are the efforts made by a large proportion of our industrial firms to foster commercial relations with that country. Excellent work is being done in this direction by the British Chamber of Commerce of Egypt, but this organisation requires a larger and more representative membership to give it the authority and weight necessary to secure reforms still urgently needed for facilitating business intercourse between Egypt and Great Britain. The annual subscription is purely nominal, and in return the chamber furnishes members with monthly and annual trade reports, undertakes the recommendation of agents, the supply of information, and is generally at the service of members for any purpose likely to promote their commercial interests.

FOREIGN ENGINEERS AND EGYPT.—Not only are foreigners very ready to support organisations for the collection and dissemination of commercial intelligence, but they display much enterprise in the establishment of direct agencies in countries where business is desired. The adoption of the last mentioned policy has been very successful in Egypt, and accounts for the numerous engineering works that have been executed by French, German, and Belgian engineers in that country. For instance, the tramways of Cairo are engineered by a Brussels company; the lighting concessions for Suez and Port Tewfik were obtained by Messrs. H. Beyts and Company; a French engineer is now commencing the transmission of electric power for irrigation pumps; Siemens-Schuckert electric motor plants have been introduced in sundry cotton plantations; the gates of the Assuan dam are operated by the motors of the same firm; French electricians, until recently, have carried out the bulk of the lighting systems in Egypt; concrete steel construction is almost entirely in the hands of French firms; Swiss pumping plant is extensively employed; Belgian joists and German rails are largely imported, and lifts for buildings usually come from Italy. There is really no reason why foreign engineers should be allowed to take the lion's share of Egyptian trade, and we hope the present order of things may speedily be reversed.

DOVER HARBOUR. — Referring to the article on the National Harbour at Dover which will be found elsewhere in our present number, we may add that the Admiralty engineers have recently been engaged in the preparation of designs for the construction of a depôt for submarines similar to those already established at Portsmouth and Plymouth. Tenders are also being invited for electric hauling gear to be applied to the heads of the East and Admiralty piers, and to each end of the Island breakwater, in order that steel cables may be drawn across the intervening channels so as to close the harbour in time of need.

STEEL RAILWAY CARS.—Nearly twenty years ago the Great Northern Railway were running steel-bodied passenger coaches on their Scotch express service, but for some reason this excellent innovation did not become permanent. We are now glad to learn that the Brush Engineering Company have undertaken the building of steel railway cars such as are in extensive use on the other side of the Atlantic. The additional steadiness of the steel car should tend to reduce the number of derailments, and when mishaps have occurred it will certainly obviate the telescoping, splintering, and ignition of vehicles which inflict so much additional and unnecessary suffering upon those who are unfortunate enough to participate in railway accidents.

THE PORT OF LONDON.—Nothing could be more prejudicial to the commerce of the Port of London than the incessant and abortive attempts at legislation which have taken place within recent years. We are now left with the very modest Bill of the Thames Conservancy, which proposes little more than the dredging of a 30-ft. channel from Gravesend to the Nore, the cost of this channel to be defrayed by the increased taxation of shipping. Compared with the extensive programmes arranged by the port authorities of Liverpool and Antwerp this is a very meagre proposal, and the method of recoupment equally undesirable. It is to be hoped that the forthcoming discussion of the Bill in the House of Commons will have the effect of leading to the institution of more satisfactory measures.

ENGINEERING APPLIANCES IN FOREIGN PORTS.—Various semi-official visits have been paid during the last few months to foreign ports with the object of collecting information relative to dock extensions and the mechanical appliances used in connection with the handling of materials and merchandise. The Thames Conservancy Board have taken considerable interest in the great undertaking about to be commenced at Antwerp, and a deputation of the Shipping Federation, including delegates from the chief ports of the United Kingdom, visited the same place, in June last, to inquire into the projected port extension, and to inspect the arrangements made in respect of labour organisation. Sir Christopher Furness and several members of Parliament are now on a tour of inspection among French, German, Belgian, and Dutch ports with the object of observing the facilities furnished for the economical and rapid handling of cargo. Sir Christopher has already expressed himself as being much struck with the superiority of the equipment provided on the Continent, and we trust that the information obtained by him and his party will result in some interesting developments when the Port of London Bill comes before Parliament.

MOTOR DRIVEN MACHINE TOOLS.—While the losses of power in transmission by shafting and belting are very generally represented by 50 per cent. of the output at the engine, the corresponding losses in the case of electric transmission from engine to tool are rarely more than 25 per cent. But it must be borne in mind that losses for mechanical transmission are constant and that those for electric transmission vary with the energy consumed. Hence the power required for electrically-driven tools is usually much less than half that necessary for belt-driven tools. In addition to the saving of power, electric driving possesses the further advantage, that a greater output per machine is obtainable, owing to the flexibility of the method, and, further, its cleanliness and the non-obstruction to artificial and natural light are features of much importance in many engineering workshops.

LONG DISTANCE POWER TRANSMISSION.—In discussing the economical possibilities of electric power transmission before the American Institution of Electrical Engineers, Mr. Ralph D. Mershon expressed the opinion that the controlling factors are the cost of power at the generating station, and the price that can be obtained for the power delivered. As he pointed out, the elements included in the annual cost per kilowatt for transmission, excepting those dependent upon the line conductors, can be reduced by increasing the quantity of power to be transmitted. The first cost of the line conductors can only be reduced by increasing the voltage, and as there is a limit to such increase, it follows that the maximum distance to which power can be economically transmitted depends upon the cost of the conductors. Assuming 300,000 kilowatts as a maximum supply, Mr. Mershon arrives at the conclusion that power transmission is not practicable beyond a distance of 500 miles. The same subject was discussed at the recent meeting of the British Association, where Mr. Hammond, referring to the utilisation of the Victoria Falls, stated the opinion that although there were no engineering difficulties in the way of supplying electric energy to all the mines on the Rand from a central power house at the falls, the cost would far outweigh the annual outlay on coal. In this case, the demand is necessarily small at the present time, consequently the radius of economical supply is considerably less than it will be after a few years have elapsed.

AMERICAN RAILWAY BRIDGES. — The appalling disaster which occurred to an excursion train on the Atlantic Coast Railway when crossing a bridge over the Elizabeth River should have the effect of directing further attention to the insecurity of numerous railway bridges in the United States. On the occasion to which we refer the bridge is said to have snapped in two like a piece of rotten wood, precipitating the engine and three cars into the river below. When the railway system was first introduced into the United States, timber bridges were chiefly employed, and such of them as still survive constitute a menace to the safety of the travelling public, because these structures are quite unsuitable for modern rolling-stock. After some years had passed, iron bridges were built for new railways, but as early American engineers unwisely declined to profit by British experience and adopted untried types of design, it is not surprising that many of their bridges developed weak points after a few years of traffic. An American engineering contemporary goes so far as to say that almost all the iron bridges built before the year 1875 were deficient in rigidity and lateral stability. When these defects were discovered, improvements were gradually introduced embodying more

massive construction, fewer parts, and a more liberal use of riveted connexions. Pin connected trusses were superseded by riveted trusses and plate girders and other successive changes were made which have had the effect of bringing modern bridge design in the United States fairly up to the standard prevailing in this country. American railway engineers are now busily engaged in replacing timber bridges and the earlier iron bridges by steel structures of more substantial design, and it is probable that railway passengers of the future will be able to journey from place to place without having to consider whether the train will drop through the first bridge and find an impromptu terminus at the bottom of some river or ravine.

THE RATING QUESTION.—In view of the quinquennial valuation now being made, considerable uneasiness prevails among the industrial classes of the metropolis. This is very natural, for it is well-known that the London County Council are doing their best to induce the local assessment authorities to regard machinery as a controlling factor in settling the basis of taxation. The borough councils will probably be only too willing to seize upon any means by which they may derive more money wherewith to continue their career of extravagance, and the recent circular of the London Machinery League is most opportune. All who approach the general problem with open minds must see the reasonableness of the contention that movable machinery should be exempt from taxation. We trust that a satisfactory response will be forthcoming to the appeal for support from provincial as well as from metropolitan firms. The unfair rating of machinery, however, extends far beyond the boundaries of London, and it is really time that the manufacturers of Great Britain should unite to demand the reversal of existing methods.

CANADIAN IRON.—Steady progress continues in the production of Canadian pig iron, and there is reason for gratulation in the fact that the output for the first six months of 1905 was the largest yet attained in the history of the Dominion iron trade. Before 1902 the production of pig iron in that country never reached 100,000 tons. Last year the amount was over 270,000 tons, and if the figures for the first half of the present year are maintained, the output for 1905 should be well over 400,000 tons. For the last three half-years the figures are 120,643 tons, 150,299 tons, and 210,208 tons respectively. This is an excellent record, showing that iron manufacture is rapidly becoming one of the most important among Canadian industries.

THE INTERNATIONAL NAVIGATION CONGRESS.—One of the most valuable scientific meetings of the year is now in progress at Milan under the auspices of the International Association of Navigation Congresses. This organisation continues the work of nine previous conferences, the last of which was at Dusseldorf in 1902. The chief value to this country of the papers read will probably be in connection with the subject of inland waterways. Considering the urgent necessity that exists for the regeneration of British canals and for the introduction of modern systems of traction such as are employed with such marked success on the Continent, there is every reason for welcoming the congress and the subsequent publication of the papers submitted for discussion.

THE IDIOSYNCRASIES OF STEEL.—In an instructive paper with the somewhat dubious title, "Steel as an Igneous Rock," Professor Arnold, of Sheffield, recounted to the members of the British Association some of the peculiarities of steel. Our readers are sufficiently familiar with the mysterious failures to which this material is occasionally liable, and will quite agree with the statement that it is generally reliable in 9,999 cases, while in the 10,000th case the material, after having successfully passed all known tests, may suddenly fail more like glass than a ductile metal. Professor Arnold has done most useful work in the way of steel research for some years, but has not yet been able to learn the secret of this apparently simple but really highly complex substance.

OPENING OF THE VICTORIA FALLS BRIDGE.—One of the most interesting functions of the British Association meeting last month was the opening of the Victoria Falls bridge by Professor Darwin. We have already described and illustrated* this fine example of engineering work, and need not now refer to its constructional features. Thanks to the energy with which the splendid conception of Cecil Rhodes has been realised in part, those participating in the opening of the bridge were conveyed in electrically lighted sleeping and restaurant cars to the site, to find which explorers in the past had spent weary months, often without success.

* THE ENGINEERING REVIEW, vol. x., p. 244.

How a Crane Shop is Run.

By JOSEPH HORNER, A.M.I.Mech.E.

CRANE making is now a very extensive industry, with which the writer has had a great deal to do, dating from the early days of the steam cranes. Since that period it has become so highly specialised, that, as in machine tool manufacture, we find the old general firms lessening their range of manufacture, while many new ones have taken up individual branches of the work. The greatest fillip to crane making has been given by the application of electric power. This has effected greater changes in design during ten years than all other agencies had produced in any previous decade.

In writing of the methods adopted in the construction of cranes, we must cover ground which is occupied by the general industry, rather than that of special shops. How wide that field is, few save crane builders know, including, as it does, every class of hoisting machine, from the little pulley blocks or the hand winch to the immense armed Titan, or the Goliath, or bridge or cantilever cranes.

One of the difficulties which general crane manufacturers experience is, that they cannot take full advantage of the methods of repetitive and interchangeable production. It is not possible to make cranes uniform to the same extent as machine tools, and stock them with fixed gauge, constant radius, type of jib, or girders, identical castings, etc., and uniform grade of workmanship. There are several reasons for this, the bottom fact of which is that nearly every separate customer wants something different from others,—different gauge and radius, something cheap for temporary service, or good for permanent use, which again affects the question of the use of iron, steel, or gunmetal, phosphor bronze, or rawhide, and of fine, or "good enough" workmanship. So it has always been, and must apparently continue to be for an indefinite period to come.

It is easier to specialise in the smaller hoisting machines than in the larger kinds. Big cranes are seldom ordered except singly, or in twos or threes, and nothing for these, save some smaller fittings which they have in common with others, can be safely stocked. So that here a broad division occurs at once.

But in the smaller tackle, and in cranes of medium dimensions, stock can be safely carried; seldom as complete structures however, but as component parts, in this respect resembling the practice of the machine tool makers, who carry in store spindles, heads, tool boxes, rests, brackets, tables, &c. In the crane shop many common castings are stocked, and also forgings, rough and finished; and finished sections of work, as engine sets, gears, shafts, brackets, brakes, sometimes also trucks and beds, but not many jibs, or unusual forms of plated work, or massive castings beyond standard trucks and truck centres, side frames, wheel centres, and such like.

In considering these subjects in detail, as they concern the separate shops, we shall bear in mind the difference in standard and general work.

Take the case of a crane of any one size and type, say a five ton steam jib crane. It is modelled after a standard form first, of standard gauge, and of fixed radius, say 15 or 20 ft. It would usually have a truck made wholly of cast iron, and the jib would be rigid, *i.e.* not derricking. Gearing would be of iron, excepting two or three of the smallest pinions, which, being subject to much wear, are of steel. Some of the

bearings only would be brass-bushed. The crane would not be covered from the weather. On this "standard" crane the changes have to be rung if orders are to be secured from a widely varied clientèle, notwithstanding that every piece of it is considered standard, and so named when reference is made to these pieces on drawings, or in the shops. The following are common departures therefrom.

Starting from the superstructure, which is the section least subject to variation, this includes the cheeks or side frames, and their attachments, in the form of shafts, gears, &c., the principal changes in which are these:—

The substitution of steel, or gunmetal or phosphor bronze for cast iron gears, of cut gears for cast, and a more liberal use of gunmetal for bearings, so making a better class crane without any alteration in the design. Sometimes there is a stiffening up of parts of the frame, as when a jib of exceptionally long radius is used. The addition of derrick gear for luffing the jib when such is required, involves several alterations. But speaking generally, the side frames and superstructure are the most stable portions, that is, are least subject to alterations, and generally one set of patterns does duty for all castings of one particular power of crane.

The jib may be varied considerably, not only in length of radius but also in its type. It may be a straight-tapering jib, or it may be bent, or arched, or again it may be fixed or derricking. It may be either solid plated, or single, or double lattice braced, or be straight lengthwise, or cambered; it may be built of plain rolled channels, or of H sections, or its side members built with plate and angle. So that practically few cranes can ever be classed as standard absolutely, since most have to be made to suit the requirements of the ordering firm, and must be modified in form to obtain the strength and stiffness which alterations in radius, or arching, &c., demand.

The two, or three cross-tube vertical boiler is mostly used on cranes, and this is readily standardised. Only occasionally is a boiler required with more uniform steaming capacity than the vertical, and then one of the multitubular types is substituted. The truck is subject to many departures from standard. The best are built with plating, and a centre casting only, to receive the post. Besides this, alterations are made in the wheels and their bearings. Wheels of cast iron, and steel, and wheel centres with rolled steel tyres being used. Many crane trucks are built on permanent way models, with axle boxes, and slides, buffers and draw bars.

The foregoing is a concise summary of the variations which have to be made in the one particular type or size of crane just now mentioned. But as most firms make numerous types and dimensions, the amount of detail which has to be attended to in the conduct of the work is apparent. These variations affect the methods of every department, giving rise to two different classes of orders, and to two different methods of production. The first named are the job and the stock orders; the second are those of individual, or very limited production, and those in which considerable quantities of similar articles are turned out.

The job system of manufacture cannot be economical regarded in the light of modern ideas, though it is unavoidable in the case of all large cranes, and of every special form of crane made. In the case of a Goliath or Titan, a specially large derrick, an overhead travelling crane, the drawings must be got out for that particular job, and it must be carried through all the shops as a single order. But economies are effected as follows:

A set of drawings does not mean that the job is started *ab initio*. Many details from older drawings are taken *en bloc*, and fitted in suitable places in the new crane. Here a set of engines will be taken bodily, there a train of gears, or a set of ground wheels, or even an entire crab. And then new drawings are not made for these, but the original drawings looked up, and numbered again for

the new order, with suitable remarks thereon. So that with the new drawings a number of old ones are included, and error is avoided by the remarks entered on the drawings, or in the shop specifications which are handed to the foremen of departments.

In the pattern shop it happens that there is often quite as much work involved in alterations to existing crane patterns as in making new ones. Comparatively few are kept strictly standard, in the sense of never having to be altered on any account whatever. Hence the responsibility of the foreman is great and constant, involving much re-measurement of old work, in order to prevent risk of sending patterns to be cast without putting them back into the original forms and dimensions they possessed previous to alterations. There is more risk of an oversight when a pattern has been cut, and when larger or smaller core prints have been put on, than when simple additions have been made, because the latter more readily attract attention. Even gear wheels, which one might think should never be altered, are being constantly modified in respect of bosses, shaft holes, and ribs; besides attachments cast with them—as clutches, sleeves of different lengths and diameters; while the widths of faces are frequently altered by stopping off, or by drawing in the foundry. The want therefore of uniformity in cranes presses heavily on the pattern shop, and the state of things in this shop is mostly reflected in the foundry.

The methods of the foundry in crane shops do not include much machine moulding. But on the other hand they embrace a wide and varied range of tasks in green, and dry sand, in bedding in, and turning over; in loam, in swept-up work, and cores, and considerable assistance is derived from bottom or joint boards. Plated work, and machine moulding might be utilised in a larger degree than they are, if more stock were carried, and more of this could be done in many shops than is usually handled. Though therefore the foundry of the crane shop handles a speciality, its methods are mainly those of the general shop. It also commonly includes brass work as well as iron, and day work is most often the method of payment. Outside orders of a miscellaneous character are also frequently taken.

But the small class of cranes are frequently made in sets, from half-a-dozen sets upwards, and are charged into a stock order number, certain portions being omitted, as jibs, and trucks, practically thus confining the stock to the superstructures. Further economy is studied by limiting the sub-orders to certain portions of the superstructures, as cheeks, stretchers, or cross girders, and the larger gears and main engines; work, the use of which is restricted to one size of crane; and putting in separate orders for some other portions which are employed on cranes that vary in power. Thus, there are some small gears which may be utilised on say two or more groups of cranes, nearly alike in size, and hand wheels, steam flanges, and valves, glands, bushes, &c., and which in a careful system are interchangeable on those different cranes. These are stocked distinct from the crane orders, and in much larger sets as a safe stock. Some of these are also frequently wanted for renewals without delay in delivery. Many are used also on cranes dissimilar from the standard types, and these points are all considered in determining how much stock of any kind shall be carried. In the foundry such articles are plated, and moulded by hand methods, or in some progressive shops, made by machine. When wanted they are charged from stock to the order on which they are required.

With regard to the methods of moulding adopted, green sand and turning over are usual for side frames, cross girders, and gear wheels. The last named, when of large or moderate dimensions are made by machine from a tooth block, using a core box, and sweeping boards. An alternative way is to make an iron pattern, moulded by machine, or machine cut, and mould from that. Time is saved, and the

results are satisfactory. Cut gears are necessary for high speed electric cranes, for which blanks are cast.

Bedding-in is done in the case of beds, truck centres, footplates, occasionally also with side frames. Dry sand work is reserved chiefly for the largest spiral drums used for wire rope or chain. These are made mostly from loam patterns, or sometimes from patterns of wood, being in this case formed in cores. Worm wheels are properly moulded in dry sand, so are cylinders, and cross head guides, and small gears also, when clutches and bosses which have to be turned are cast with them. Loam moulds are made for swept-up spiral drums, but beyond these loam work in crane shops is mostly applied to outside orders, such as soap and lead pans, large engine cylinders, turbine work, etc. Cores, small and large, are used in nearly every casting on a crane. The largest are those for beds, and truck centres, for drums, and heavy gears. Some are made in boxes, some swept up.

Orders are given from the pattern shop into the foundry on slips of paper, or cards, either for single castings, or for sets of work, for stock. For single orders of cranes, the castings must be ordered separately as the patterns are got ready, but for stock the whole set for iron can be covered by one order. But even then it is better to issue separate orders for each piece or each sub-set, because of the convenience of each man's job being charged out to him. Alternatively, though, this can be done by a foundry clerk. The orders are given of course by their order number, as well as by the name of the piece, or pieces, and these numbers are retained throughout from the pattern shop to the finished work. On the paper slip or the card the moulder's time occupied is entered, and the price, if done by piece-work, the weight also of the fettled casting, and any explanatory remarks that may be desirable.

In the smithy, both hand forging, and die stamping are utilised. Crane work lends itself very well to the latter, since there are so many articles repeated, as hooks, swivels, tie rod eyes, engine parts, and numerous levers of various kinds. Excepting for unusual shapes, for special cranes, more than half the work in the smithy can be done with the aid of stamps. Sometimes the process will be a finishing one only, completing work neatly and uniformly which has been already brought nearly to shape on the anvil. But there is much besides which can be done wholly in dies, in one or more stages. In this department also, standardisation of parts is carried out extensively, so that the difference of a ton or two in the power of a crane is not allowed to make differences in many of the forgings, such as tie rod ends, levers, forked ends for operating clutches, engine connecting rods, swivels, shafts, and many other articles. Bolt-making machines and hot and cold iron saws are freely used in the smithy. Many bolts are of sizes and lengths which are not carried in ordinary stock, and shafts and spindles are better sawn than marked and broken off from bar.

There is a good deal of plated work and boiler work in cranes. Large numbers, even of small cranes, now have plated trucks, instead of cast iron ones, and all large cranes must have their framings built up thus. In big goliaths and titans the plating runs into some scores of tons in weight. Cheeks and side frames are also often built of plating, using cast iron bosses only for the shaft holes. Jibs are nearly always plated, the alternative being timber. Some crane manufacturers send all this kind of work out to be done by the bridge building firms, but this is not so desirable as doing it on the premises. Very little of this work can be done for stock, the exception being a few jibs and trucks for types for which there is a fairly steady demand in the firm's business.

Templets are readily used for certain sections of the plating. Thus, trucks and jibs of one size have all their members sawn, planed, and punched from templets. The saving in time is that

of the marking out, and this, when a number of bevelled ends and holes are concerned, is considerable. When jibs and truck frames or side frames are marked out for the first time, for a new job, or the first of a job intended to be standard, it is always drawn to full size on a floor or board, and if templets are made therefrom they are tried in their places on the drawing on the floor or board. They are not finally passed for permanent use until the crane has been fitted up, and any corrections found necessary made.

Unusual rolled sections are seldom required in crane work. Those which are employed, besides plates, are square angles, mostly equal sided, tees, rolled channels, H sections, and flat bars, seldom anything besides. Sketch plates are required for side frames, and for portions of titan framings. Steel alone is now used, iron having been displaced long since. But iron is used in many forgings, especially where welds have to be made, and for hooks.

The work of the angle iron smith is in constant request in the plated work of cranes. Angles are required for the borders of nearly all side frames, and these are, in good work, bent round the curved portions, and welded up as a complete frame to be riveted on the plate. Diaphragms and stiffeners of tee or angle are wanted in all heavy crane frames, and these have to be bent, set, or welded.

Steam boilers are made, and kept in stock in considerable numbers. They vary in size, and in number of cross tubes, with cranes of different powers. They are built to a stock order number, and charged out therefore singly when wanted for individual cranes. They are always made to templets, the edges of plates being planed, and holes drilled, or well reamered after punching. The work of the angle iron smith consists in making the angle rings, the cross tubes, the uptake, and the rings that surround the fire door, mud holes, and man hole. Flanging is sometimes done by hand, by the aid of templet blocks. It includes the boiler shell and fire box crowns, the cross tube ends, and the uptake base. But crowns are commonly stamped in a flanging press, being ordered out if a firm does not possess a plant of sufficient power. Nearly all the work in the smithy, plating, and boiler shops is done by the piece, being very much cut-and-dried, and repetitive in character. The price is based either on tonnage, or per article.

Following the work into the turnery, machine, and erecting shops, boring is done in considerable quantities, the principal work being the bearings of cheeks and trucks; engine cylinders, and circular cross head guides. The work is done on drilling machines, boring machines, and in lathes, depending mainly on the size and character of the pieces. There are two main differences in this respect, that of parts done singly, away from the other portions of the crane, and that of parts when bolted up in position. The first is often relegated mostly to the lathe and drilling machine, the second to the boring machines as follows:—

Top cross heads are bored for their post heads in the lathe. Various brackets that are being faced in the lathe are bored at the same setting; so are wheels and pulleys, cylinder covers and glands. Cheeks and brackets are frequently drilled, bored and faced at the same time, and same setting, on the table of a drilling machine, the facing then being done by a flat cutter wedged in a bar which just fills the hole first bored, and which is driven by the drilling spindle. The advantage gained is that of doing the work at one setting. The objection is, though a very slight one, that when a pair of cheeks are bolted up to their cross stretchers the bored holes may not come absolutely in line, and then a little scraping has to be done to make the shaft bed properly in its bearings. But the bearings are never very long, seldom amounting to two diameters in length, so that error, if present, is but slight. But in many cases the frames are bored subsequently to being bolted up to their cross girders. Then the bearings are done between a pair of standards in which the boring bar is capable of a large range of vertical adjustment to

suit the extreme positions of bearings. The bars are of the slotted type, receiving flat cutters secured by wedges.

Cylinders are occasionally bored in the lathe as of old, if work presses. But boring machines of the bar and of the snout type are preferable. The latter are admirably adapted for the small engines used on cranes, and the vertical type is better than the horizontal.

The methods of lining out and of templets are both adopted. There is a good deal of work that lends itself to the use of templets, and these are really necessary in order to avoid waste of time in making adjustments, on every separate crane. Interchangeability, as we understand the term in fine machine work, expressed by the term "assembling," is hardly applicable to crane work, where cross girders and cylinders have to be bolted to cheeks, and shafts, and gears, many of considerable size, fitted. Fixed gauges are, and long have been, commonly used in turning and machining, but some slight adjustments with file or scrape are generally necessary. That, however, does not affect the fact that replace parts can be sent away under this system, with the certainty that corrections will never be other than very minute. The present practice is an immense advantage on the older methods. I can well remember when a templet or fixed gauge was rare, but when nearly every piece was lined out separately and fitted to its fellow, without regard to any other crane, past or future, or even similar cranes being built to the same order. There is no part of a crane for which templets, jigs and gauges cannot be made. They are of most value in the following parts:—

The cheeks, in which the shaft holes are bored through jigs clamped upon them; the cross girders, which are planed to length by templet, and in which holes are drilled and bored by the same means; cylinders, faced, bored and drilled by templet; truck centres, planed; clutch jaws, shaped; connecting rods, bored; gear wheels, faced and bored; curb rings, faced and turned, &c. This work is done mostly by the piece, when sets are ordered, but generally by day work when single cranes of non-standard forms are being carried through. If, however, any pieces are similar to those used on standard cranes, they are charged out from stock, or done at ordinary piece prices.

The aids derived from machines of special forms are considerable, and several of these are found in the best crane shops. A goodly number of cut gears are used in electric cranes, both spur, bevel, and worm. A firm is well advised to keep, as some do, separate machines for different classes of gear. Spur wheel cutting is done better on one machine designed only for that, and bevel wheel cutting on another preferably of the planer type. A universal class of machine is not suitable for a crane shop, where the gears are mostly heavy. Worm wheels should be hobbed, and if the expense of a machine is too great for the few gears required, then they should be given out to a firm who makes a speciality of their manufacture. The vertical boring mill is a good acquisition in a crane shop. All revolving cranes have a curb ring or race, and this is set and turned much better and cheaply on a horizontal table than on a vertical face plate. Besides this, the brake wheels can be bored and turned simultaneously; and so also can ground or running wheels, wheel centres, and wheel tyres. Two machines of different sizes may be laid down with advantage, and then one can be used for turning only for those jobs which have to be turned on mandrels, or on another lathe, or small work can be bored and turned, leaving the big machine free for big work.

There is a considerable amount of milling now done in crane shops. The pieces milled are those which would otherwise go to planer, shaper, or slotter, as valve faces, and edges, clutch jaws, keygrooves, bosses, and facings, the flats of levers, cylinder ports and so on. A universal milling machine is suitable for this work.

Precision grinding is not employed as much as it might be. But the time is fast approaching when the cylindrical

grinder will be regularly used to finish work first roughed out in the lathe, and then it will be found cheaper to grind shafts and spindles than to finish-turn them. Besides this, precision grinding may well be substituted for milling, as rough grinding often does that of planing and shaping, examples being the jointing of brasses, and the flats and bosses of levers.

The erection of cranes is done both in the shop and outside; the latter being adopted only for work too big to go inside, or at those times when the volume of work is so large that the shop is crowded.

There are two kinds of erections, those over pits for deep post cranes, and fixed cranes generally, and those on rails for portable cranes, and overhead travellers. The latter requires a different arrangement from cranes which run on the floor, since the erection must take place at a sufficient height to permit of slinging the load for test beneath the traveller beams.

It is necessary to have one or more brick-lined pits in crane shops for erecting fixed cranes over. The pit is entered to one side down a ladder, in order to get at the bottoms of posts in footsteps placed in the lower part of the pit. A heavy cast plate with joggles surrounds the top of the pit, to which the base plate is bolted. When the post terminates with the bottom of the base plate, nothing more is necessary than to bolt the latter down to the joggle plate.

A crane, from the point of view of the erector, consists of two portions, the base and post and the superstructure. The latter is fitted and erected separately on wood blocking, and when complete it is lifted by the traveller and dropped bodily in place over the post and base erected over the pit. This is the second stage of the erector's work. The third consists in slipping the jib in place, securing its head with chains or tie rods to the superstructure, attaching the footplate or plates; and in the case of a steam crane, setting up the boiler also and condenser, followed by the fitting of the steam and water pipes.

When a portable crane is erected on rails a sound piece of permanent way is required on a good level foundation, so that there shall be no risk of the crane tearing up the rails when under test. The procedure of erection is similar to that of fixed cranes, the truck and post being got on the rails, and the super structure lifted over the post. In the case of overhead travellers, the main girders are carried on rails laid on timber blocking. I have frequently seen four vertical boilers used as temporary blocking. The best method is a permanent brick-lined pit.

The testing of cranes is done where they are erected, except in the small steam cranes erected in shops, which should be run out into the yard for that purpose. The object of testing is to discover weakness in construction, and insufficiency of power. The test, therefore, is always from 10 to 25 per cent. above normal loads, and is generally carried out under rather severe conditions, such as arresting movements suddenly, and lifting, travelling, &c., at maximum rates. As a rule, in the work of good firms, failures of any kind are unusual, ample margins of strength and safety being allowed. Only rarely does a large casting fracture or welds give out. An important point in balance cranes is the load which can be safely lifted across the track without blocking girders or rail clips, and the angle at which an upset would occur, if at all. In long jib cranes blocking is essential, but it should not be necessary with cranes of small radii. All cranes should lift their maximum load with the jib straight forward, and the wheel base must be calculated to ensure this. In travelling cranes the deflection of the girders under maximum test is noted. In cranes of all types maximum rates of lift, travel, and slewing are stated and tested.

After a crane is tested it is painted. Until then nothing besides a coating of boiled oil, to afford protection from rust while the work is proceeding, is permitted in a strict specification. One coat is generally given after testing, as

the crane stands. Then adjacent parts are stencilled with reference letters, and all taken apart, and a second or third coat given to the separate pieces. Turned and bored portions are simply rubbed with tallow. Packing of small parts is done in wooden cases, the larger sections are sent uncovered. Various necessary precautions are taken in packing.

Orders for repairs and renewals to cranes are constantly coming in. If the repairs involved are serious, due to the fracture of main parts, as cheeks or trucks, or the severe bending of jibs due to the fracture of main parts, to oversetting, it is generally necessary to bring the cranes back to the shops. But fractures of small portions and renewals due to wear and tear can be generally effected by sending new parts away. There are certain portions which wear more rapidly than others, and these are kept in stock, finished and fitted, ready for instant delivery. These include slewing, lifting, and travelling gears, chiefly the pinions, jib head pulleys, barrel wheels, rollers, and curb rings, in the order here placed.

The standardisation of cranes is being hastened by the application of the electric drive. Motors, switches, etc., are standardised, and as most crane makers purchase these equipments, they and their customers are getting accustomed to the idea of fixed and definite powers and dimensions. In a sense, too, the work of the crane makers is becoming simplified by this latest agency. It has given a new birth to the simple worm drive, and ousted correspondingly, trains of bevel and spur gears, and the heavy shafts which used up power extravagantly. The abolition, too, of engines, boiler, and pipe connections is favourable to simplification, and whatever simplifies, makes for standardisation.

Dover Harbour Works.—II.

By W. NOBLE TWELVETREES, M.I.Mech.E.

The National Harbour.—An outline sketch has already been given showing the general scope of the works included in this great undertaking. The task now remaining is to give some account of the manner in which solid and impregnable walls have been founded in the very bed of the sea and gradually raised above the surface of the water.

The whole of the works were designed by Messrs. Coode Son and Matthews, as consulting engineers, and are being executed under their supervision and that of Sir Henry Pilkington, K.C.B., chief engineer to the Naval Works Loan Department of the Admiralty, the contractors being Messrs. S. Pearson & Son, Ltd., of Westminster.

Actual operations were commenced on the site in March, 1898, but before this date extensive preparations had to be made, including the installation of plant and the collection of materials for the erection of temporary works from which operations were to be conducted.

Briefly described, the staging consisted of piles about 100 ft. long by 18 ins. square driven about 16 ft. into the bed of the sea in two sets of six at intervals of 50 ft. apart. These piles were strongly braced together and connected by steel girders on which timber decking was laid so as to form what was really a temporary pier of immense strength in order to provide for the establishment of railway lines over which all materials were conveyed and for the installation of the cranes and other machinery required.

From beginning to end four stagings have been built, one for each section of the works. For the construction of the piers and island breakwater, the staging was of such width that the permanent masonry could be laid between the outside rows of piling, the platform being at a height of 28 ft. above high water level.

Fig. 8 represents one of two steam derricks supplied by Messrs. Joseph Booth Brothers, of Rodley, for the construction of the staging. The staging

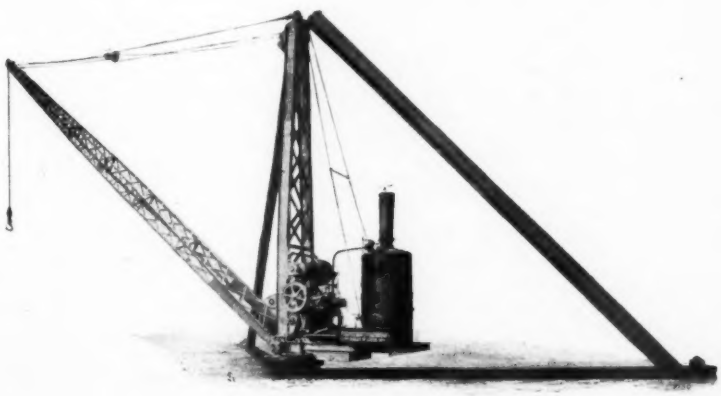


FIG. 8.—A DERRICK CRANE USED FOR STAGING.

for the reclamation wall was of generally similar construction, the top being 25 ft. above high water level.

In the first instance, the piles were of Oregon pine weighted with iron to prevent them from floating, but this material was shortly afterwards displaced by Tasmanian blue gum, which, owing to its high specific gravity, will not float in water, and is capable of resisting attack from the teredo. The magnitude of the temporary works is clearly shown by the statement that more than 1¼ million cubic feet of timber have been employed in their construction.

The work first undertaken was the reclamation of the foreshore at the eastern end of the town, and the next portion to be commenced was the Admiralty Pier Extension. Simultaneously with the erection of the temporary works preparations were made for moulding the large concrete blocks to be employed in building the permanent works.

Owing to the absence of available space at Dover, a site was secured on the eastern side of Sandwich where sand and aggregate for the concrete were provided by the immense accumulations which have long since placed a distance of some two miles between the ancient port of Sandwich and the sea. The Portland cement required was conveyed by barge from the Wouldham Cement Works on the Medway, these works being the property of the contractors. A temporary store yard for finished blocks was established on the beach outside the South Eastern Railway Town station, blocks being conveyed from Sandwich by lighters and by rail *vid* Ashford.

Fig. 9 is a photo showing part of the reclamation wall and blockyard. The length of the wall is 3,850 ft., its height from foundations to top averages 30 ft., and the roadway is 10 ft. above high water level. It is built of concrete blocks, weighing about three tons each, cemented together and faced with granite.

During the building of the wall, the

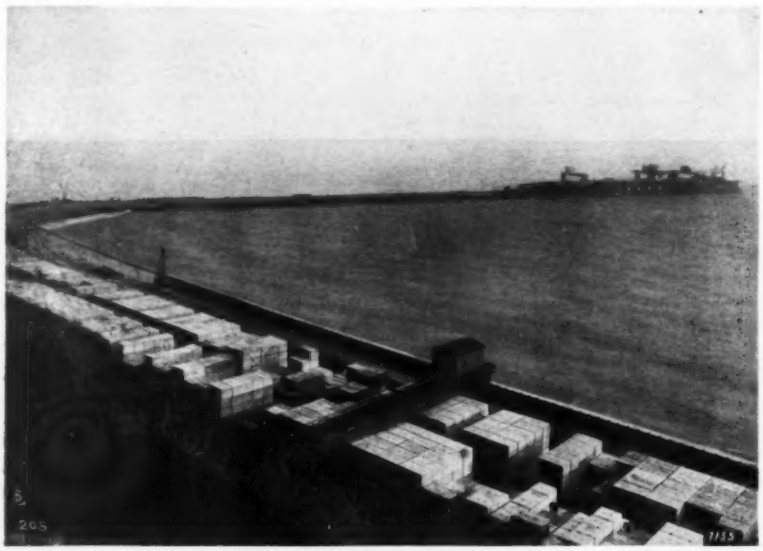


FIG. 9.—PART OF RECLAMATION WALL AND BLOCK YARD.

FIG. 10.—VIEW OF EAST PIER UNDER CONSTRUCTION.

contractors commenced to fill up the space behind it with chalk and rubble, and made use of the site for making concrete blocks. When the area of twenty-one acres between the wall and the cliffs had been reclaimed the whole of it was devoted to the manufacture and storage of blocks, and the works at Sandwich were abandoned, although sand and shingle still continued to be conveyed thence to the new block yard. The western yard adjacent to the Railway Station adjoining the Admiralty Pier was also laid out for and used for block making.

The first pile of the staging for the Admiralty Pier Extension was driven in December, 1898, and the first concrete block was laid a year later. At that time the east sea wall was not finished, but by the end of December, 1900, it had been carried to the point whence the East Pier was destined to push its way for the appointed distance 3,000 ft. along the sea bottom. The staging had already been continued round the curve (see Fig. 9) and early in January, 1901, the first block of the pier was successfully deposited on its bed. From that date until nearly the end of 1904 exceptionally rapid progress was made in the building of the eastern arm, owing in part to the close proximity of the block yard, but more particularly because the works were sheltered in great measure on the south-west by the Admiralty Pier. The extension of the latter was virtually completed in the autumn of 1904, and the final block of the East Pier, which was commenced some time later than the Admiralty Pier extension, was laid before the end of the same year.

A remarkable illustration of the great advances evidenced within recent times in constructional methods is afforded by a comparison between the progress made on the Admiralty Pier works of 1847-1871, and on the extension works of 1899-1904. In the former case the average rate of advance was 91 ft. run per annum or less than 7·6 ft. run per

month, while in the latter, the average rate was fully 50 ft. run per month. Hence Messrs. Pearson & Son have been able to accomplish in two months more work than their predecessors got through in a whole year.

Fig. 10 is a general view of the East Pier from a photo taken when that work was nearing completion.

Early in 1903 preparations were commenced for the building of the Island Breakwater between the east and west arms of the new harbour. A steel framework about 60 ft. high was erected in the yard at the foot of the East Pier, the intention being to take this structure out to sea in several sections, and to re-erect it in the required position so as to form a staging from which to drive the piles for the works of the breakwater. By adopting this method of procedure it would not be necessary to continue the staging from the adjacent pier across the eastern opening of the harbour as at first contemplated, and the work could be started on the breakwater before the actual completion of the East Pier. Finally, however, the system of staging was made continuous across the eastern entrance.

Both piers and the breakwater are monolithic structures built entirely of concrete blocks, those in the Admiralty Pier Extension weighing forty tons each, and in the East Pier and Island Breakwater thirty tons each. The blocks are keyed securely together, and above high water level the joints are cemented and the blocks are faced with granite. The typical sections of these works reproduced in Fig. 12, from a drawing furnished by Messrs. Coode Son and Matthews, will serve to give a general idea of their construction. The main dimensions are as follows:—

Admiralty Pier Extension: — Total height from foundation to parapet, 90 ft.; height from foundation to roadway, 78 ft.; width at base, 57 ft.; at road level, 42 ft.; height of roadway, above low water level, 28 ft. 9 in.; above high water level, 10 ft.

East Pier:—Total height from foundation to parapet, 85 ft.; from foundation to roadway, 78 ft.; width at base, 52 ft.; at road level, 45 ft.; height

FIG. 11.—VIEW OF BLOCK YARD.

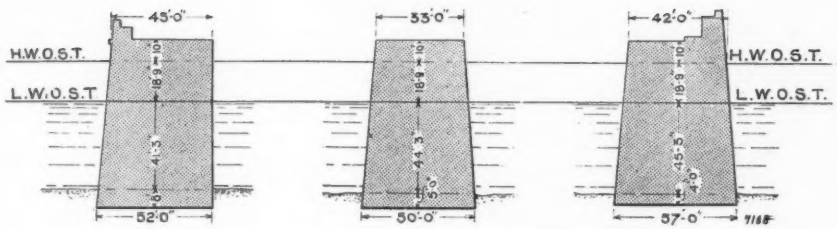


FIG. 12.—TYPICAL SECTIONS OF PIERS AND BREAKWATER.

of roadway, same as Admiralty Pier Extension.

Island Breakwater: — Height from foundation to top, 78 ft.; width, at base, 50 ft., at top, 33 ft.

These dimensions are merely approximate, and it must be understood that they are not applicable to all portions of the works. The Admiralty Pier Extension being exposed to the full force of south-westerly seas is provided with a high parapet of massive construction for the shelter of those using the pier; the parapet on the East Pier is considerably lower owing to the non-existence of passenger traffic and the less violent character of the sea on this side. The Island Breakwater of course requires no parapet, as it is not intended for promenade.

It will be observed by reference to the sections that the foundations are in each case carried down below the surface bed of the sea, the depth varying from 4 ft. to 8 ft., according to circumstances, so that the masonry may be let into the solid chalk. An apron has been constructed outside the Admiralty Pier Extension with the object of safeguarding the foundations from being undermined, but this precaution in the depth of water provided appears to be unnecessary. One matter for regret is that the symmetry of the Admiralty Pier was spoiled by the refusal of the War Office to permit any interference with the fort at the original end of the structure. This caused a good deal of unnecessary expense, and is mentioned here for the purpose of recording the fact that the Admiralty are in no way responsible for the somewhat ungainly form of the pier at the junction of the old and new work.

In the present article it would be quite impossible to refer at any length to constructive details attending the construction of the harbour works. The utmost that can be attempted is to describe the general method of procedure, and to give some account of the concrete making and other contractors' plant employed.

Let us begin at the block yard at the foot of the East Cliff. Here the area of twenty-one acres was occupied by an extensive concrete plant occupying a central position, and stacks of finished blocks at either end, those at the east being conveyed on railway trucks along the new pier, and those at the west being transported by barge along the Admiralty Pier from a jetty built by the contractors. This jetty being also used for the unloading of materials and stores of all kinds.

During an earlier stage, this jetty was employed for landing blocks from the Sandwich establishment. Fig. 11 gives a good idea of the stacks of finished blocks near the East Pier.

At a point near the middle of the yard is a staging upon the platform of which sand and shingle are delivered by trucks running up and down a cliff railway or lift. The trucks are filled at the top of the cliff with material brought from Sandwich by rail *via* Martin Mill, and the weight of the full trucks provides the motive power for hoisting empty trucks, the only attention required being the application of a brake

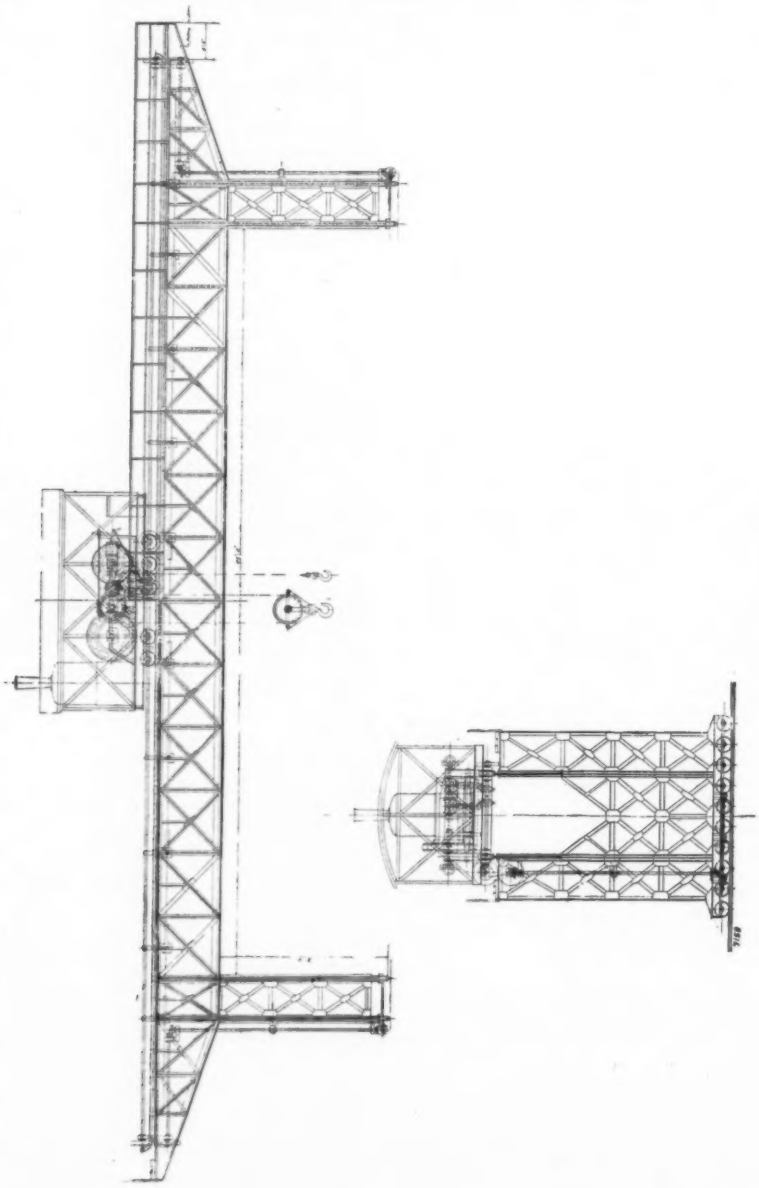


FIG. 13.—42-TON GOLIATH CRANE.

to prevent the attainment of excessive speed. Cement is transported from storage sheds to the mixing platform by an electrically-driven screw conveyor. All the dry materials necessary for the concrete are delivered into gauges in the predetermined proportions of six to one. There are six of these gauges, and the contents of any one can be discharged through shoots into one of six portable concrete mixers beneath the platform, water being added in sufficient volume to give a semi-fluid consistency to the concrete. Timber moulds for block making are disposed in long lines down the yard, and over them are six elevated railway tracks, mixing being performed on the way. Sixteen revolutions of the drum are required for the adequate mixing of the materials. In order to make sure that no mistakes shall occur, the number of revolutions is automatically indicated on a dial attached to the machine.

When the mixer has arrived over the mould selected the sides are opened by means of a lever and the concrete pours out. The machine is then returned to the mixing stage for a fresh charge. After the concrete in the block has been allowed to harden for two days the sides of the mould are removed, and in eight days more the block is sufficiently hardened for removal to the store yard.

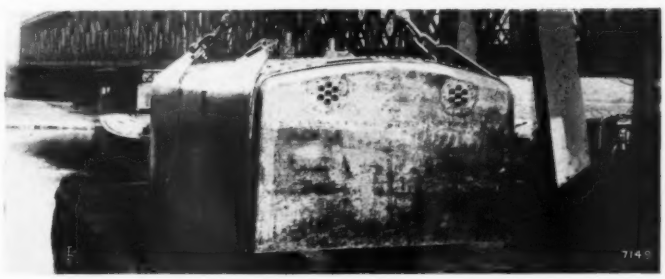


FIG. 14.—DIVING BELL.

one for each of the portable concrete mixers. The mixers are of the type made by Messrs. Stothert and Pitt, of Bath, but the trucks on which they are placed at Dover were designed and built by Messrs. Pearson & Sons. These trucks are propelled by electric motors, the necessary current, by which also the mechanism of the mixer is operated, being supplied by the mains of the Dover Corporation Electricity Station.

As arranged in the Dover block yard, the concrete mixer is an admirable labour and time-saving apparatus. As soon as the charge of cement, sand, shingle, and water has been received the revolving drum is set in motion, and starts on its journey to the mould which has to be filled, the operation of The mould is then re-erected for the formation of another block. The blocks are allowed to season for at least six weeks before being used in the construction of the piers.

For the purpose of handling the blocks, a set of six railway lines has been laid down along the whole length of the yard, and upon these run goliath cranes and railway engines.

One of eight 42-ton steam goliaths supplied by Messrs. Ransomes and Rapier, of Ipswich, for the Dover Harbour Works will be seen in Fig. 9, and a similar crane made by Messrs. Joseph Booth and Brothers, of Rodley, is illustrated in Fig. 13.

It should be mentioned that for the purpose of facilitating the handling each

of the blocks is cored by two holes running in a sloping direction from top to bottom, these holes being formed by the temporary insertion of timbers in the mould. Being coated with grease before the concrete is deposited, these core prints are readily removed after the concrete has set. When a block has to be shifted, a steel bar having the lower part bent into a T end so as to engage the lower surface of the concrete is dropped through each hole, and the upper end of each bar being hooked on to the chain connected with the crane it is very easy to hoist the block. As already mentioned all blocks above low water level are faced with granite. The facing is built up in the moulds by masons in the work yard, and after the concrete has been added the whole sets into a monolithic mass. The courses are of different widths so as to afford a satisfactory key for the concrete. Nearly all the granite for this purpose has been furnished from the contractors' quarries at Gunnislake, in Cornwall. In addition to the cores, each block is moulded with vertical grooves in the sides so that the blocks can be securely keyed together by the use of cement grout.

In executing the permanent work of the piers and breakwater, the following general method was adopted. The first step is the construction of the temporary staging by the aid of pile drivers and derrick cranes. Then three goliaths are erected at specified intervals for the simultaneous conduct of three distinct operations:—(1) Excavation, (2) Levelling, and (3) Block laying.

While these operations are being performed a further forward length of the staging is under construction. By the time the operations have been completed within the range of the three goliaths, the extension of the staging is ready and the three machines are moved forward. In actual practice the work of stage building often advanced far more rapidly than the other operations.

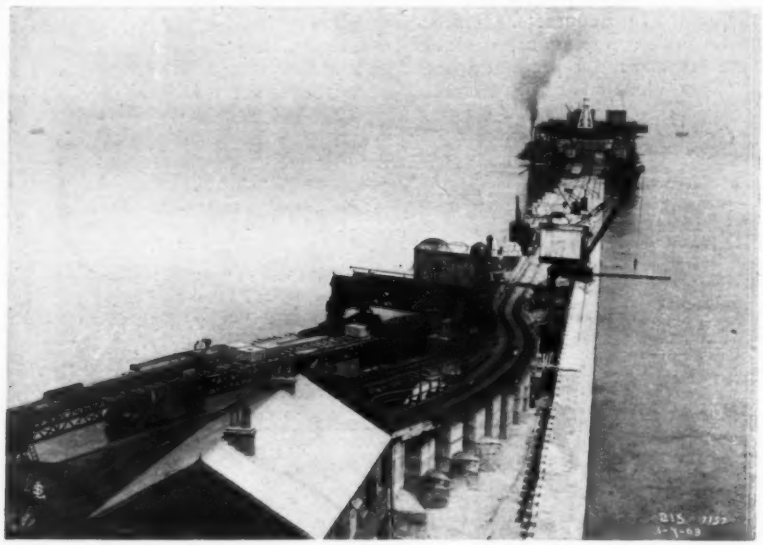


FIG. 15.—ADMIRALTY PIER EXTENSION.

The foremost goliath is employed for lowering and raising the Hone grabs by which the necessary excavation was made for the foundation blocks of the piers and breakwater. The material removed is loaded into barges which are towed out to sea for a distance of three miles where the cargo is discharged into deep water.

The second goliath is used for manipulating the diving bells employed for the purpose of levelling the foundation bed. Fig. 14 illustrates one of the bells supplied by Messrs. Hunter and English, of Bow. The largest bells employed measure 17 ft. long by 11 ft. 6 in. wide by 6 ft. high, and all of them are lighted by electricity.

The third goliath is employed for lowering the concrete blocks, first upon the levelled foundations and then upon the successive courses of masonry. The work of block setting is performed by helmet divers who descend from boats moored inside the staging.

Figs. 15 and 16 are reproduced from photographs of the Admiralty Pier extension, the first of these views giving a good general idea of the works, and the second illustrating the granite face pier head when nearing completion.

By the methods here described the boundary walls of the great harbour have been gradually raised above the surface of the sea. Within the last quarter of a century many triumphs of engineering skill have been witnessed, but none of these can compare with the victories won over the raging sea during the building of the National harbour at Dover. For six winters the fiercest storms have been set at naught and the work has been carried on without intermission and without disaster to the permanent work. Only those who really know the sea can adequately realise what this means and appreciate at their true worth the genius of the designers and the executive skill of the contractors.

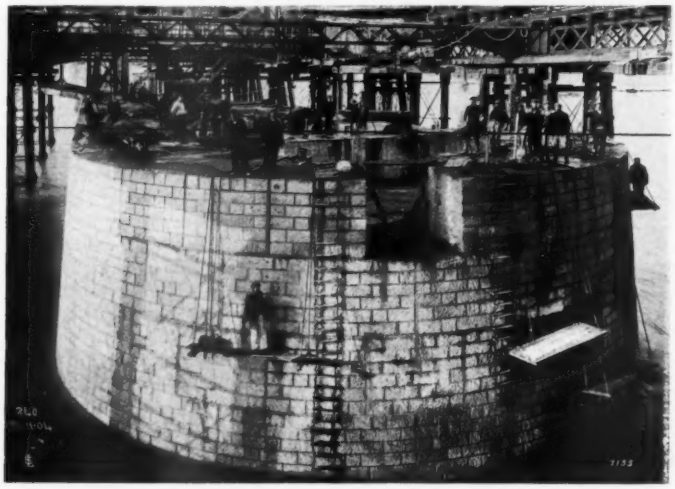


FIG. 16.—ADMIRALTY PIER HEAD.

The Port of Dover.—In conclusion, we have to direct attention to the scheme of development now about to be carried out by the Dover Harbour Board. In

the first part of the present article an account was given of the works hitherto completed by that body. Important as these are, they represent only an instalment of the works that have become urgently necessary for enabling the authorities to cope with the accession of traffic brought to Dover by various lines of Transatlantic and other ocean steamers. For the ordinary Continental traffic, sufficient accommodation already exists, but to provide for the ships of the Hamburg-American, the Nord-Deutsche, the Deutsche-Oest-Afrika, the Hamburg-South American, the Deutsche-Levant, and the Shire lines, considerable extensions are imperatively demanded. Some of these lines have already arranged for their vessels to call regularly at Dover, negotiations are pending in the case of others, and, in addition, it is not improbable that the Cunard and Wilson liners will also make Dover a port of call.

The "Port of Call" traffic commenced on July 1st, 1904, with the visit of the *Deutschland*, belonging to the Hamburg-American line, and its remarkable increase is shown by the subjoined returns giving the weekly number of passengers for July and August, this year and last year :—

Week Ending	1904.	1995.
July 8th ...	86	569
,, 15th ...	200	359
,, 22nd...	189	449
,, 29th ...	130	179
Aug. 5th ...	202	403
,, 12th ...	158	469
,, 19th ...	307	451
,, 26th ...	231	337
Totals ...	1,503	3,216

Referring to Fig. 3, p. 225, it will be seen that the idea once was to widen the Prince of Wales pier so as to give ample quay room for dealing with ocean steamships on one side and smaller vessels on the other. This scheme had to be abandoned, because of an intimation from the Admiralty that it might be inconvenient for the eastern side of the pier to be used in this manner. Consequently, the Harbour Board entered into negotiations with the Admiralty, with the result that the following points have been agreed :—

(1.) That the Harbour Board shall have a lease of the Admiralty Pier Extension, for the purpose of accommodating ocean steamships, and

(2.) That the Admiralty shall have the use of the Prince of Wales pier for the purposes of embarkation for the Royal Navy.

As our readers are aware, the harbour authorities already have a lease of the older portion of the Admiralty Pier, which will continue to be used for Continental traffic, while the extension will in future provide deep-water landing stages for Transatlantic and other large vessels. Bearing in mind the fact that the Admiralty Pier Extension gives a low-water depth of forty feet in place of thirty feet at the Prince of Wales Pier, it is evident that this arrangement embodies an important advantage.

Another result of the agreement is, that instead of building a marine station on the Prince of Wales Pier, or between that pier and the foot of the Admiralty Pier, as formerly proposed, the Harbour Board propose to widen the Admiralty Pier with the object of affording sufficient width for the establishment of a really adequate railway station, and all the accommodation necessary for the convenience and comfort of passengers.

At the moment, we are unable to give details of this new scheme, for the simple reason that the Harbour Board have only just commissioned the engineers by whom the works are to be designed and executed. As part of the scheme involves additions to work already completed by Messrs. Coode, Son and Matthews, it was thought desirable that this firm should undertake the masonry work up to the coping level of the Admiralty Pier. The other portion relating to the design and construction of the new railway station, and to all structural work connected with the embarcation and disembarcation of passengers, has been entrusted to Mr. Walmisley, the engineer to the Harbour Board.

The Locomotives of the Liège Exhibition.

By CHARLES R. KING.

THE locomotives shown at the Liège International Exhibition are especially worthy of notice, for they embody the most advanced practice in locomotive engineering since the period of the great exhibition at Vincennes in 1900. The locomotives exhibited at the Paris Exhibition are not only dwarfed by a comparison with the size of those of the Liège Exhibition, but a vast improvement has since been effected in the design and by the creation of new types. The progress made in that short period of five years is very remarkable. This advance was to be easily foreseen in 1900 and 1901, when greater improvements were already being effected by railway companies exhibiting locomotives at Paris; and it is now equally apparent that even the locomotives shown at Liège will have become small in proportion to the engines which will be constructed five years hence. Then, the limits of the constructive gauges of Western Europe (Spain excepted) will have been reached, for they are relatively small compared with those of Central Europe. In fact, constructive gauges increase in size the more we proceed from the West to the East of Europe, and, consequently, those countries nearest to England will be the first to be cramped in the building of very large locomotives.

At Liège only two countries exhibit locomotives, namely, Belgium and France. All the main-line companies of France take part in the display. The exhibition of Belgian locomotives is very fine indeed, and will have surprised many, for although Belgium took such a prominent place for railway exhibits at the Champ-de-Mars, Paris, in 1889, the poor and meagre exhibits of Vincennes in 1900 caused the observer to infer that Belgian initiative had fallen very much in that interval of years. Now, in 1905, Belgium again advances to the first rank for national and original locomotive design, and it will be a matter for suprise if within the next five years following Belgian engineers do not constitute types of locomotives evolved entirely from their own special aptitude in this branch of engineering. Belgian engineers have, it will be remembered, left names in connection with locomotive engines as have done few—instance Egide Walschaerts (pronounced Vahlskairt), and Belpaire. The wide fire-box of Belpaire, intended for burning slack, and ultimately having 57 sq. ft. grate area, now only survives in the oldest express locomotives of Belgium, and the Walschaerts valve gear (invented sixty-one years ago and perfected in 1848, or only one year in advance of the almost identical mechanism of Waldegg Von Heusinger) has had but a small application in modern Belgian express locomotives, which have nearly always been (until this year) inside-cylinder engines, and the Walschaerts gear when fitted has usually been modified by the employment of excentrics instead of outside cranks. It is certainly very remarkable to find no express engines of the Belgian State railways, after all these years, fitted with the standard gear of Walschaerts, outside of the frames, although it has been employed, to the exclusion of almost all other mechanisms for many years past, throughout the Continent save Belgium. This year, only, the most notable feature in the new Belgian locomotive types is the Walschaerts's valve motion, now introduced along with four cylinders—single-expansion or compounded. Locomotives of the French type have, it is true, been used for some

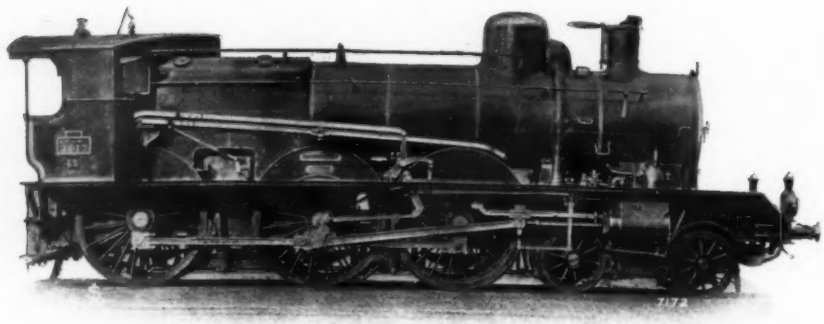


FIG. 1.—NEW TYPE OF 4-CYLINDER COMPOUND, PARIS, LYONS, AND MEDITERRANEAN RAILWAY. DERIVED FROM THE HEAVY COMPOUNDS; THE FIRST OF THE MODERN 4-CYLINDER COMPOUNDS AT WORK IN FRANCE.

years on the small Nord-Belge line, and, consequently, they had the valve motion of Walschaerts, but these engines belong to the French Nord Railway, and are not Belgian types.

To describe all the new French and Belgian locomotives exhibited at Liège, even superficially, would necessitate much space, it is therefore proposed in the present notes to deal with the subject synthetically, while the illustrations will enable the reader to form an idea of the individual characteristics of each locomotive.

Boiler Construction.—All the French locomotives have boilers with flat-topped fire-boxes of modified Belpaire type. The barrel is telescopic as usual, and the smoke-box tube plate is circular and flanged. Boiler construction is still very similar to that practised in France for some years past, and is therefore well known. The grates have been extended in length, as no more space is available between the frames for width, and to assist the coal forward the grates are steeply inclined—which arrangement enables the fire-box to be kept low down over the trailing coupled axle—for three coupled axles are becoming the rule with engines handling the most important express traffic in France. French engineers keep a low centre of gravity for their boilers, the highest mounted boiler being only 8 ft. 6 in. The desire to place the fire-box clear above the frames appears less in France than in countries farther east. A notable exception occurs in the 16-wheeled duplex locomotive of the Nord, in which a somewhat shallow fire-box is mounted above the central frame, the height of the boiler being 9 ft. $2\frac{1}{8}$ in. The total height of a French engine does not usually exceed that of the new P. L. M. locomotives (14 ft.), but in the latest types for the Western Railway the height (14 ft. $1\frac{1}{4}$ in.) exceeds that of all locomotives on exhibition. Serve ribbed tubes are almost exclusively employed for French locomotives. In the details may be noted the method of joining the inner fire-box to the shell, or wrapper, with the new Paris, Lyons, and Mediterranean locomotives (Fig. 1) The fire-hole ring is suppressed (as in the Webb plan), the flanged or pressed edges of both sheets being turned over quite square, and the overlapping edges simply riveted together. In the same boilers a sight hole is provided above the fire-door to note the state of the tubes and brick arch while on duty. Steam domes are not usually placed on the front ring of the barrel, but as there are only two rings in the boilers of the P. L. M. locomotives, it has been deemed more practical to locate it upon the short front ring. The Nord engine, Atlantic type, has three rings with the

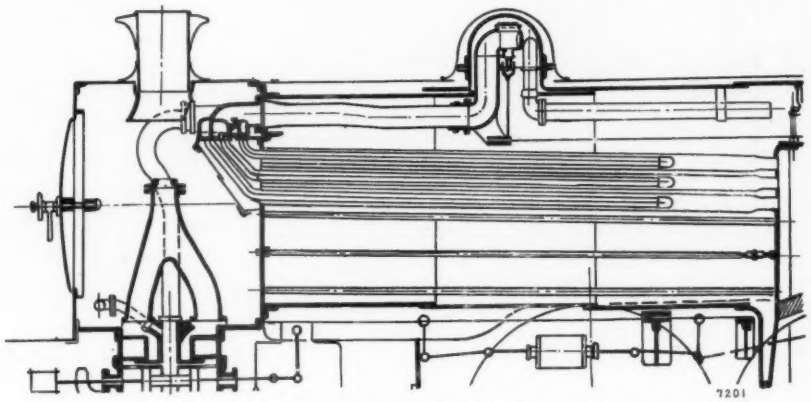


FIG. 2.—DETAILS OF SCHMIDT SUPERHEATER, BELGIAN STATE RAILWAYS.

dome in the middle. In the P. L. M. locomotive, and also with the "La Meuse" Belgian engine, steam is collected near the fire-box and delivered to the dome, in which a balanced regulator valve (drop-seat) is provided. Flat throttles are still usual with other French locomotives. Steam pipes placed outside the boiler continue permanently as the exclusive mark of French practice from the earliest days. The occasion to abandon them was a favourable one in the newest P. L. M. locomotive—since the steam dome is contiguous to the smoke-box as well as to the cylinders—but this has not been done. The new P. L. M. locomotive boilers no longer carry a sand-box, this having been placed tranversely between the frames and filled from hoppers at each side of the engine. The large and somewhat conspicuous safety valves in French

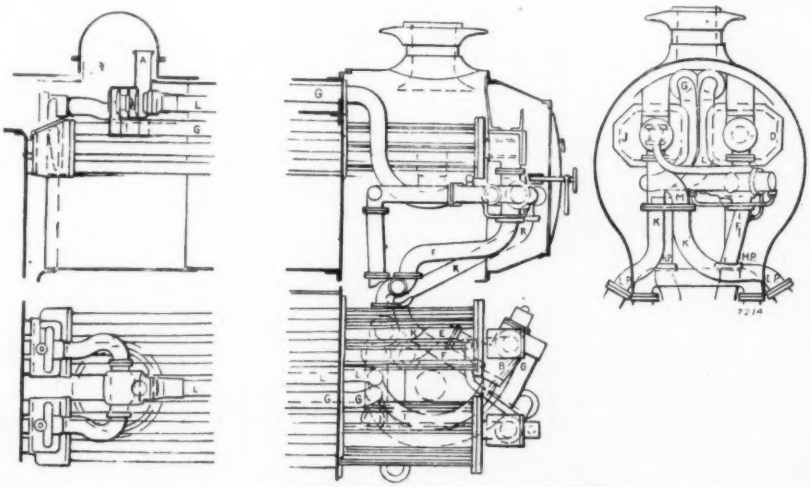


FIG. 3.—COCKERILL SUPERHEATER FOR COMPOUND LOCOMOTIVES

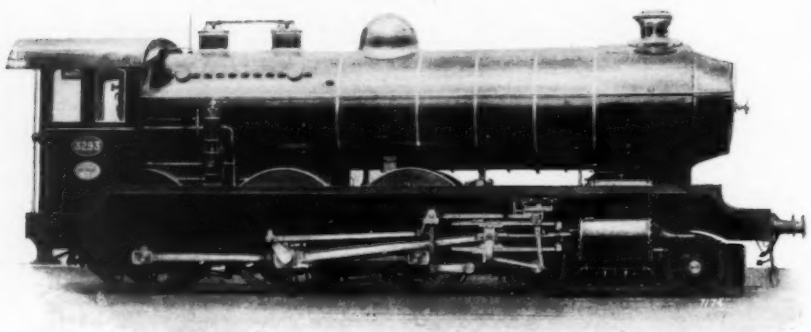


FIG. 4.—CLASS 19A, 4-CYLINDER LOCOMOTIVE FITTED WITH COCKERILL SUPERHEATER, BELGIAN STATE RAILWAYS. P. L. M. SYSTEM OF CONSTRUCTION.

boilers have here been replaced by a couple of diminutive pop valves on the second boiler ring.

Belgian Boilers.—The Belgian locomotive boilers are all of what is termed the "Stephenson" type, with the two exceptions of the De Glehn locomotive of the Nord Belge and the De Glehn locomotives just built in Belgium for the State Railways. The reintroduction of the "Stephenson" type boiler is directly due to the importation of the locomotive types of the Caledonian Railway a few years ago. It has a round-topped fire-box shell, and the usual flat smoke-box tube-plate of the "Stephenson" boiler. The reasons for the reintroduction in Belgium of the deep fire-box in place of the Belpaire wide-fire-box must be familiar to all readers, It was said that a deep fire was essential to hauling big loads at high speeds on the severe gradients of the State Railways, and that the poor quality slack coal, until then used, was unsuited for deep fires. The motive for the choice of that particular model of English locomotive selected is not very clear. A locomotive is indigenous, and rarely thrives when transplanted. It is unquestionable that the "Stephenson" boiler will endure for some time to come in Belgium, and then, together with the machinery, there may be a lapse to the practice now prevailing in neighbouring countries. At present, and as they have been altered in their proportions for burning briquettes, the existing boilers give complete satisfaction.

Economies having been realised in Austria, Saxony, Germany, and the United States, with superheated steam; these "Stephenson" boilers are also fitted with reheating apparatus—one of the Cockerill system and the other a new combination of Schmidt and State Railway ideas. While often referring to these appliances the writer repudiates all commercially interested motives in such applications the interest of which is their novelty, and also because superheating is the *furor* of the moment. It must be acknowledged, however, that the Cockerill superheater, which takes its name from the great steel works and rolling mills at Seraing, is a really very ingenious apparatus, promising to become the means of teaching much about superheating that is at present only known in theory.

The Schmidt-Etat Belge arrangement for single-expansion locomotives has the merit of great simplicity. Briefly described, a steam-pipe is led into one of the boiler tubes, there to become heated, and is then bent and led out again into a reservoir in the smoke-box, whence the heated steam is conveyed to the

cylinder (see Fig. 2). The idea is patented. In this invention there are two steam-pipes in each fire-tube. These pipes reach almost to the fire-box, and then return by the same course to the smoke-box. The steam from the boiler is obliged to make the entire circuit, since the superheated steam reservoir is cut off from that compartment which distributes saturated steam to the reheating pipes. There are, of course, a number of adjuncts, flaps, traps, thermometers, pyrometers, &c., in connection with the apparatus, to control the amount of reheating and to mitigate the inconveniences common to steam of high temperatures.

In the Cockerill arrangement, the steam reheating pipes are divided into two groups, on the right and left-hand sides of the boiler. Instead of two pipes entering and returning to the same end again, there are three pipes through which steam enters but does not return except in passing to the opposite side of the boiler, and then it comes back to the smoke-box end through a similar group of pipes. This system requires separate chambers or collectors for the steam at both ends of the pipes; that is, two in the smoke-box and two close up against the fire-box tube plate. At this end the combustion chamber enclosing the steam collectors consists of oblong rectangular boxes intervening between the ends of the large fire flues (containing the reheating pipes) and very short pieces of tubes riveted into the fire-box tube sheet. Inside the combustion chambers are the steam collectors, riveted to the ends of the reheating pipes. The collectors form a diaphragm across the path of the flames, and must thereby be subjected to very powerful heating effects apart from the heating in the pipes themselves. The steam only leaves this diaphragm-collector to enter another at the opposite side of the fire-box tube-sheet. It is thus reheated a second time before entering the low-pressure cylinders. In the case just mentioned the apparatus is considered to be working only as a receiver-superheater in a four-cylinder compound engine and as applied to engines of Class 19. It can, however, be used as a superheater for the high-pressure cylinder first, and then afterwards as a receiver-superheater for the low-pressure cylinders, the heated steam in this case passing, from back to front, through one set of pipes to the high-pressure cylinders, returning therefrom by a special pipe of large diameter in order to be sent forward again through the opposite set of pipes to the low-pressure cylinders. These movements for the steam's flow are all under control by the driver's regulator, which connects to a similar regulator in the smoke-box. To explain the different

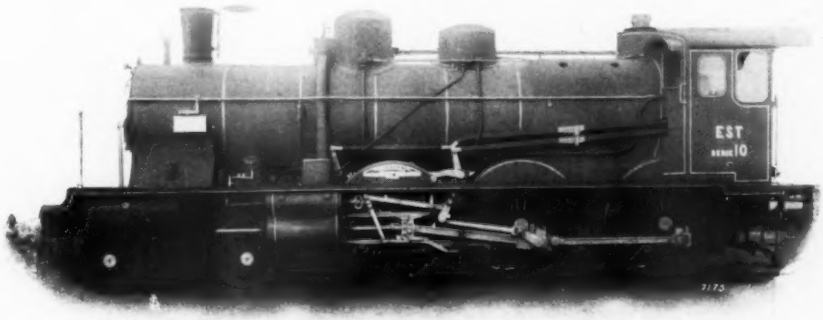


FIG. 5.—LATEST TYPE OF EASTERN RAILWAY OF FRANCE 4-CYLINDER EXPRESS COMPOUND LOCOMOTIVE. (THE LARGER-WHEELED ENGINES, WITH FLAT VALVES, &C., DO NOT REPRESENT THE MOST ADVANCED PRACTICE OF THE "EST," AND ARE TO BE CONVERTED TO THIS NEW SYSTEM.)

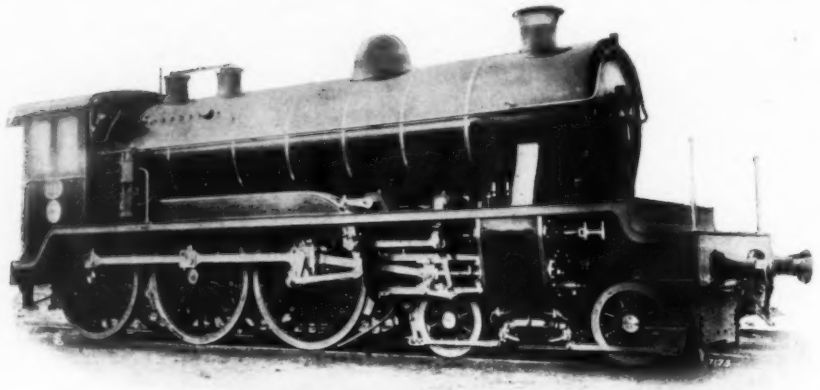


FIG. 6.—NEW 4-CYLINDER SINGLE EXPANSION LOCOMOTIVE "LA MEUSE" TYPE, FITTED WITH SCHMIDT SUPERHEATER.

movements, it is necessary to refer to a diagram. (Fig. 3.) At the bottom of the steam-pipe in the dome is a three-way valve, and another is located in the smoke box at B1. (See Plan.) These are connected together to operate simultaneously. Working as a receiver-superheater only, steam is admitted, as usual, to the pipe, L, and thence to the high-pressure cylinders, passing, on its way, through the valve B1. The exhaust from the high-pressure cylinders passes up pipe, F, through valve B1, into left-hand collector or receiver, D, through the left-hand reheating battery into the diaphragm-collector next the fire-box. Thence it passes on along a curved pipe, through the valve B, to the opposite, or right-hand, diaphragm-collector, in the combustion chamber, and so forward again, through the right-hand superheating battery, into collector J and then down by pipe K into the low-pressure valve chests. When to work as a superheater for each group of cylinders the motion of the steam is reversed. Steam is then passed through valve B back into the diaphragm-collector

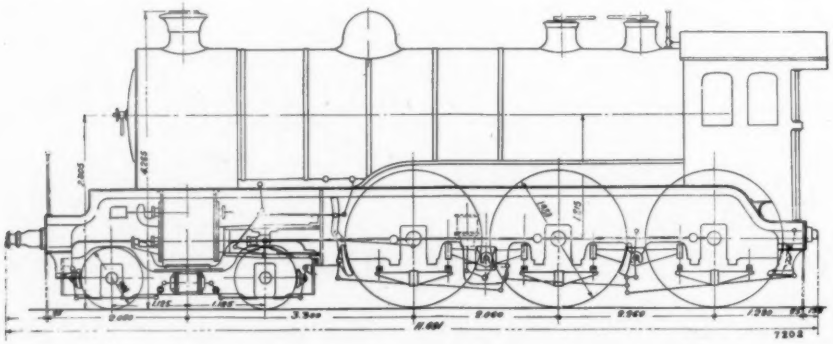


FIG. 7.—DIAGRAM OF THE ABOVE ENGINE.

on the left-hand side, forward through the battery of pipes into collector D, through valve B1, into pipe E (See Plan) and into the H.P. valve chests. The cylinder exhaust goes up through the valve B1 into the special large pipe G (See two longitudinal sections), and so by the curved transverse pipe into the right-hand superheating battery, then forward into the collector J and down by pipe K to the low-pressure valve chest. As described this double-action superheater appears complicated; but it will show, practically, which method of working is best. When this is done the two three-

by M. Henry, of the P. L. M. railways, and since followed by M. de Glehn and Mr. Webb. Six railways employ two complete sets of valve mechanisms for each pair of cylinders, so as to be able to vary the cut-off independently in each high-pressure and low-pressure group. But, of these, one (the P. L. M. railway) employs a special mechanism which obliges the low-pressure valve gear to give full travel to its valves whatever be the cut-off given to the high-pressure valves. The cut-off of the low-pressure remains constant at 63 per cent., while the high-pressure may vary from 20 to

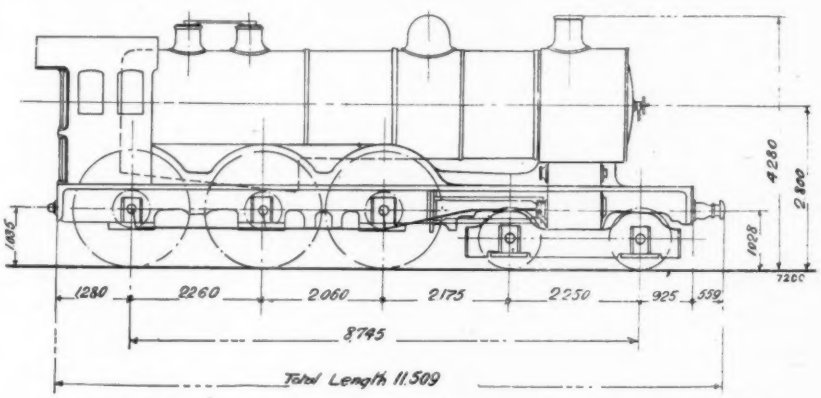


FIG. 8.—LATEST CENTRAL EUROPEAN COMPOUND LOCOMOTIVE, CLASS 19, FOR BELGIAN STATE RAILWAYS, FITTED WITH COCKERILL SUPERHEATER.

way valves mentioned will be suppressed in Class 19 A, together with several of the smoke box pipes. The second and third engines of Class 19 A will have simple receiver-superheaters as in Class 19.

Engines and Mechanism.—In the French express engines little change from standard practice is to be observed in the motion work. Out of the seven principal main-line railways, five still maintain the position, first indicated by Mr. Webb, for the high-pressure cylinders, and one railway keeps to the Central European position. All driving wheels are coupled according to the practice first adopted for four-cylinder compounds

88 per cent. of the piston stroke. This is the closest approach in French engines to Central European practice, in which latter two separate and independent valve motions have been abandoned, it having been found, after long practice, that the duplication was an unnecessary complication productive of no advantage either in speed or in coal economy; hence in Central Europe only one set of valve gears, giving proportionately longer cut-offs in the low-pressure cylinders, is the standard practice, save where the low-pressure cylinders have three times the volume of the high-pressure cylinders, in which case the cut-off allowed is nearly identical

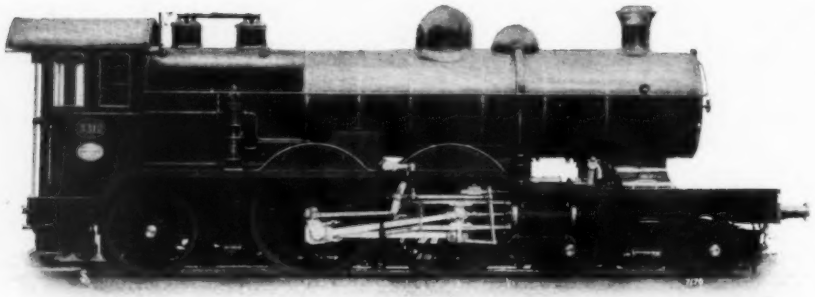


FIG. 9.—NEW "ATLANTIC" TYPE LOCOMOTIVE, DE GLEHN MODEL, JUST BUILT FOR STATE RAILWAYS OF BELGIUM. TO BE TESTED IN COMPARISON WITH "CALEDONIAN" TYPE.

in both groups. This is the case with the new Belgian locomotives. The Central European types are simpler in construction, simpler to work, and have a higher mechanical efficiency with less internal friction than the French types, which are now being abandoned in European countries where they were formerly at work; and it is a matter for general surprise that American or English engineers should have followed the older rather than the more modern practice of Europe in the types recently imported. The explanation seems to reside in the high speeds attained upon the Northern Railway of France, and also upon the P. & O. Railway of France, where high speeds have been possible more from the splendid and easy conditions of the tracks and the relatively high velocities which have always been the rule (especially on the Nord and before the days of compounds), than from locomotive efficiency or power; and it is safe to say that if the Nord eventually adopted the Central European types, or a modification of them, much higher speeds would be a practical possibility. The strongest partisans of the de Glehn model adhere closely to the original design for their locomotives, these companies being the Nord, the Paris-Orleans, and the Midi (Southern Railway), all having flat valves which, in the opinion of M. de Glehn, are the best. But four of the companies show locomotives with piston valves which, in nearly all cases, give inside admission. The first railway to adopt these valves for four-cylinder

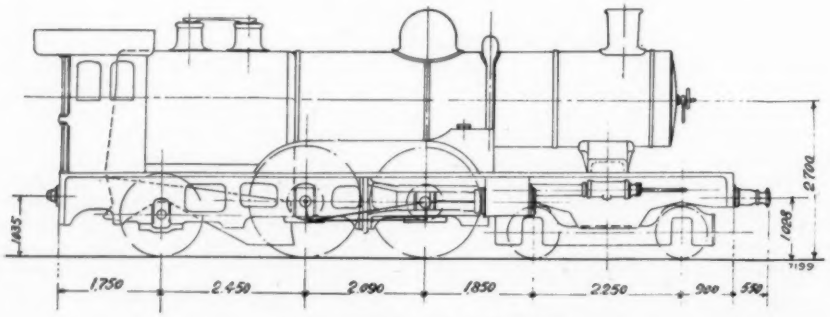
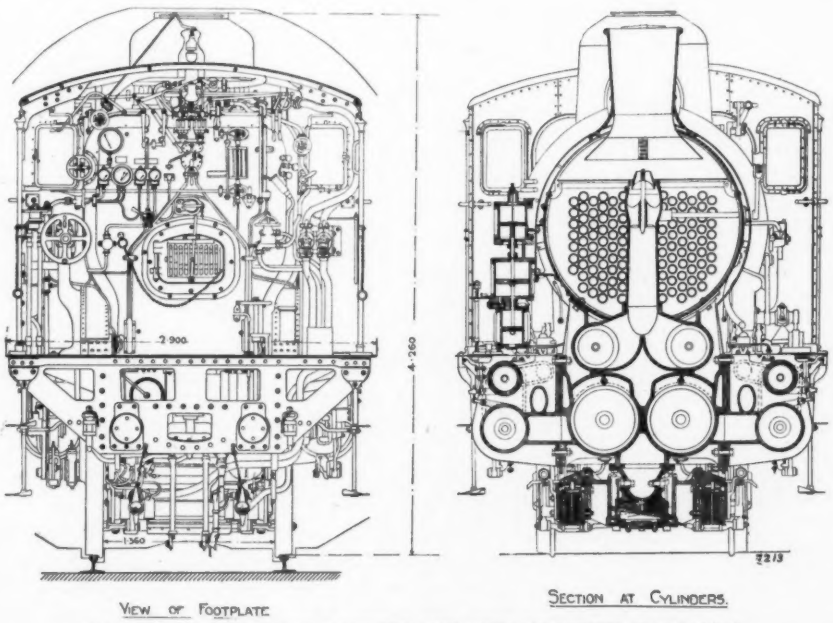


FIG. 9A.—DIAGRAM OF THE ABOVE ENGINE.

compounds was the Est—now some three years since. The results have been so good that the P. L. M. and the Ouest companies have also fitted these valves to their most important express engines. But the first railway to employ piston valves for single expansion engines was the "State," they being now in regular use for some twenty-five years—always of the Ricour type. The engine exhibited by the Etat at Liège is a two-cylinder compound of Nadal's system having, as in the Berth engine of the same line, two piston valves to each cylinder (one for admission, one for exhaust), and it has the Walschaerts gear in inverted position. The Ricour valve, with its elastic ring filled with steam, is already well known. It is satisfactory to note that ordinary cast-iron segments are the rule with all the new piston valves, for the compressible segments of bronze, used in some countries, have given very inferior results from their rapid wear.

One of the objections sometimes urged against piston valves is the large clearance volumes which they are said to entail. Quite on the contrary, the clearance volume can easily be made much less than is even desirable for free steaming in a compound locomotive. The P. L. M. locomotive shown has clearance volumes for high and low-pressure cylinders respectively, of only 10·55 and 6·28 per cent.—exceedingly low figures compared with the de Glehn express locomotives of the Nord, wherein flat slide-valves are used. Volumes of only 10 and 7½ per cent. have been arranged in locomotives of Adriatic type, having only one piston valve for two cylinders, and these were found too little. The new Belgian compounds have the H. P. steam passages greatly enlarged to give capacious clearance volumes and so avoid excessive compression where super-heated steam is used.

The one valve gear of the exhibition



VIEW OF FOOTPLATE. SECTION AT CYLINDERS.

FIG. 10.—4-CYLINDER COMPOUND LOCOMOTIVE, PARIS, LYONS AND MEDITERRANEAN RAILWAY.

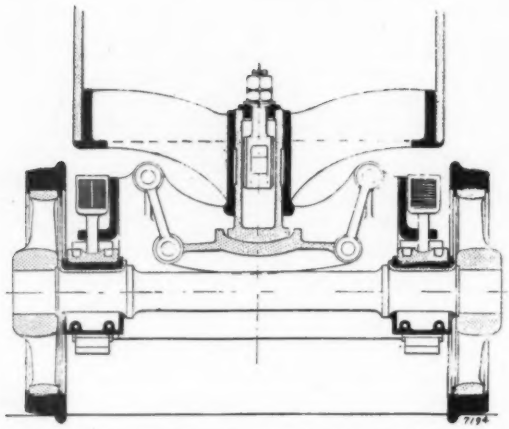


FIG. 11.—SWING PONY BISSEL TRUCK OF 4-CYLINDER COMPOUND LOCOMOTIVE, SOUTHERN RAILWAYS OF FRANCE.

is the Walschaerts. The few exceptions with Stephenson gear are in the applications to Caledonian models. The variety of designs in Walschaerts's gear is shown by our illustrations. Interesting to note are the long radius bar and long lead-lever of the P. L. M. express locomotive and the reversed valve motion of the six-connected Class 19 A (Fig. 4) compound of the Belgian Railways. Means for taking up the wear in pins and eyes of the valve motion are provided in some locomotives. This is best illustrated in the Eastern of France six-coupled engine, where a buckle is provided at the end of the valve-rod spindles (see Fig. 5) and the valve crank rod even has adjustable ends—which is very unusual. In all the Belgian express locomotives of modern design—that is of Central European type—only one valve gear is used for each pair of cylinders. Motion in one pair of valves has therefore to be transmitted through rock-levers. The most unusual example of rock-levers is seen in the new four-cylinder single-expansion locomotives of "La Meuse" type. This is visible in the diagram (Fig. 7) and in the photograph of this engine (Fig. 6.) All connection between the outside valve gear and the outside valves is broken off. Instead, the ends of the lead levers drive a rocking shaft and the inside valves. The extensions to the high-pressure inside valve-spindles are connected with transverse rocking levers (pivoted to heavy brackets outside of the frames), and these levers are connected by links to the front ends of the low pressure valve-spindles—an arrangement used also in Mr. Webb's four-cylinder compounds of Central European type. The object of this arrangement is to cause each valve to admit steam at its inside edges and without having to reverse the normal positions of the valve mechanism as is done with the Class 19 A, with the Est engine and with the P. L. M. engine shown at Liège. In all the new four-cylinder engines for the Belgian State Railways, transverse rocking levers are introduced, so as to give inside admission to all valves. In Classes 19 and 19 A the normal valve gear is reversed in its movements, and the rocking levers effect the re-reversal of direction for the inside set of valves. As the arrangements are novel, diagrams of the motion will be given* of the three engines "La Meuse," Class 19 and Class 19 A. The two last, only, have reversed action in the outside valve mechanism, as will be detected in the photograph of Class 19 A.

The rocking levers, and the guides for the valve-spindles in the Belgian locomotives of the Class 19 A, (Fig. 4) form altogether a very fine piece of mechanism, massive and with broad and ample bearings and bearing-surfaces, calculated to drive without strain the valve-spindles of the most overheated of valves for distributing super-heated steam. The pivots of the transverse rock levers are of great depth and the free ends of the levers are doubly linked to the valve-spindle guide, first at the top and then below just above the radius-rod. A number of arrangements are in existence for obviating torsional

stresses which, in ordinarily designed gears of this system, are liable to occur because of the lead lever, and in its connections to the crosshead not lying in the same vertical plane as the valve-spindle. The above described gears avoid torsional stresses, as do also the special valve-spindle guides of the Nord engines. A very massive valve-spindle slide is also fitted to the five 2–8-0 four-cylinder goods locomotives of the Southern Railway of France exhibited here, and having the same object. Another arrangement to be found in the powerful eight-coupled "pushers" at work at Liège is a forking of the advance levers for working on each side of the crosshead guides, but the most perfect of all systems for avoiding torsional stresses is that which passes the lead-lever through the guide-bars, or else is in duplicate throughout, on each side of the guide-bars, and as applied to the Adriatic compounds. In the P. L. M. compound the lead-lever is ingeniously passed through a slot in the single guide-bar. Single guide-bars, more common in Italy and Austria, are very scarce at the Liège Exhibition, the most notable exception being the locomotive of the Paris, Lyons and Mediterranean Railway. In this case the bar is fluted and of great length in order to enable the forwardly-placed cylinders, by means of a very long piston rod, to reach back to the second pair of drivers. The same difficulty occurred with the new Belgian compounds of Class 19 A, but to a less extent, as the driving wheels in this case are much smaller in diameter. The great length of the piston rod in this latter is partly supported by the very unusual cylinder covers of deep conical pattern, as will be noticed in the photograph (Fig. 4.) This Belgian engine really belongs to the P. L. M. model (created in 1888) in that, notwithstanding the forward position of the cylinders, the second pair of driving wheels are connected to the outside cylinders and the first pair to the inside cylinders, thus dividing the motor stresses, as first practised by Mr. Webb. Here it may be noted that in all the new four-cylinder Belgian compounds the Central European practice is followed of placing the low-pressure cylinders outside, which is contrary to French custom save for the Midi goods engine exhibited. In the case of using only one pair of valve gears, this is best, for then only a small pair of valves has to be driven through the rocking levers. The locomotive, Class 19 A, is therefore a compromise of two systems: The Central European and the early Webb. But the locomotive Class 19 (see Fig. 8) with the larger driving wheels for faster traffic,

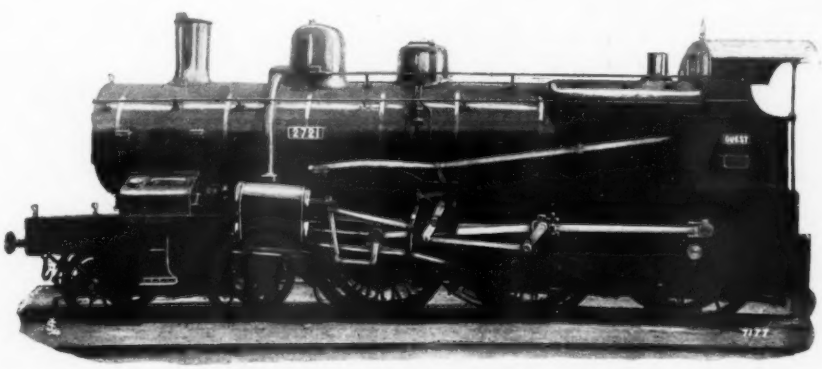


FIG. 12.—NEW TYPE 4-CYLINDER COMPOUND WITH PISTON VALVES, WESTERN RAILWAY OF FRANCE.

belongs to the first system, as does also the engine called "La Meuse" in these notes. This latter is, however, a single expansion locomotive which is a mere detail, for it could be very easily converted to compound, and much more readily than to connect the outer pair of cylinders to the second pair of drivers as the makers (La Sociètè de la Meuse) mention as being possible in case the leading axle became fatigued with four cranks turning at it. The State Railways of Belgium are about to determine by practical applications which is the best all round plan: all crank efforts upon one pair of wheels, or divided, according to the early Webb and, more recently, to M. de Glehn. To make the tests complete, locomotives of the exact de Glehn model—more powerful than those of the Paris-Orleans or Pennsylvania RR.—have also been built and one is exhibited at Liège (see Fig. 9 and Diagram 9A). Very little doubt is held as to what will be the issue, or survival of the fittest, in the trial of the Caledonian, de Glehn "Atlantic" and Central European types. Four-coupled engines are quite inadequate for the heavy traffic of Belgium where long runs at high speeds are impracticable. Consequently the French type, to take a fair part in the ordinary services, needs 6-coupled wheels, and a number of such machines have just commenced work, although not represented at the exhibition.

The oblique-arm crank axle, of modified Martin pattern, is now introduced in several Belgian locomotives—notably in Class 19 and "La Meuse" (Fig. 6), and as employed for a number of years past in Central Europe, and also in France—including also the Nord-Belge line belonging to the Nord of France. This is a very strong cranked axle and is often made hollow throughout, save in the oblique portion. It is not fitted to all French locomotives, as, for instance, of the Nord and P. L. M., but it has had extended application on the locomotives of the Est and Ouest. In Belgium it is called a **Z**-axle.

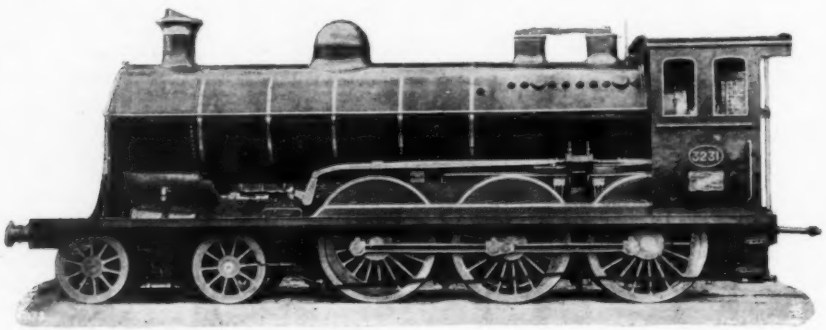


FIG. 13.—SIX-COUPLED SINGLE EXPANSION SUPER-HEATING ENGINE, "ENERGIE," FOR HEAVY AND PASSENGER SERVICE ON STEEP GRADIENTS.

A remarkable fact to note at Liège is that a great number of coupling-rods, and even main-driving rods also, are of flat section—not channelled—contrary to the practice of late years, during which it has been common to channel everything, even the rods of the valve motion and the weigh bars or reversing rods. The Belgian locomotive "La Meuse," many of the "Caledonian" model, the new duplex compound goods locomotive of the French "Nord," the new compound of the Ouest, are examples. In

others, as the six-coupled express engine of the Paris-Orleans lines, the goods engine of the Midi and most of the new type Belgian engines, only the main driving rods are fluted, I-section. Side rod ends in the "Caledonian" models are plain eyes, bushed. In the new Belgian types a return is now made to adjustable rod ends, and those usually of box pattern. French designers do not appear to approve of plain rod ends at all. In the Est six-coupled engine box and strapped ends are used in the same coupling-rods. The P. L. M., the Nord, the Ouest, the Midi, and the P. and O. show marine-type ends for coupling rods, similar to the driving rod big-ends of the Belgian locomotives, "La Meuse," Class 19, and Class 19 A, Fig. 4. In all French six-coupled locomotives, the main rod must necessarily be fitted outside of the coupling rods. In the Central European types of the Belgian State Railways, the advantage is seized, in driving upon the first pair of coupled wheels, to place the main rod to the inside of the coupling rod. A reference is here suggested to the diagram showing the engine-motion of "La Meuse," Class 19, and Class 19 A. Stress on the driving pins is, thus, much reduced, the engine runs steadier, and the coupling rods can be removed more readily for renewal of brasses. This is, however, only one of a half-dozen very important points of superiority which could be named in favour of the Central European types, and well known to all engineers who have had prolonged experience with these and the French types, both of which, it is very curious to remark, are typified in Mr. Webb's three and four-cylinder compounds, exception made for the difference of valve gear. Readers interested in the question could not do better than read the letters by Professor Von Borries, which have been written to the contemporary press. The question of axle-box wear on one side, and fatigue in crank axles on the other, is a most attractive one. But the whole matter will be solved, not by theory, but by practice, and for this reason, it is

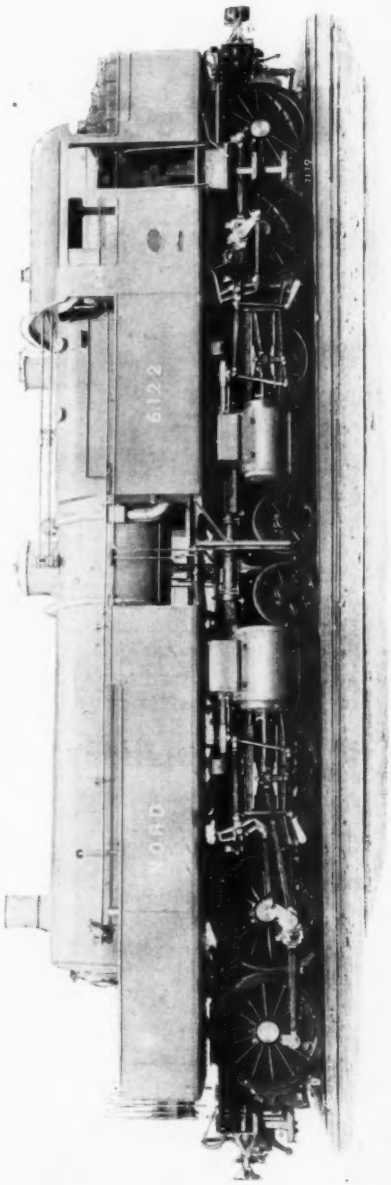


FIG. 14.—16-WHEELED GOODS LOCOMOTIVE DUPLEX COMPOUND OF NEW TYPE BY M. DU BOUSQUET FOR THE "NORD" EXPRESS COAL TRAINS, TO HAUL 1,000 TONS.

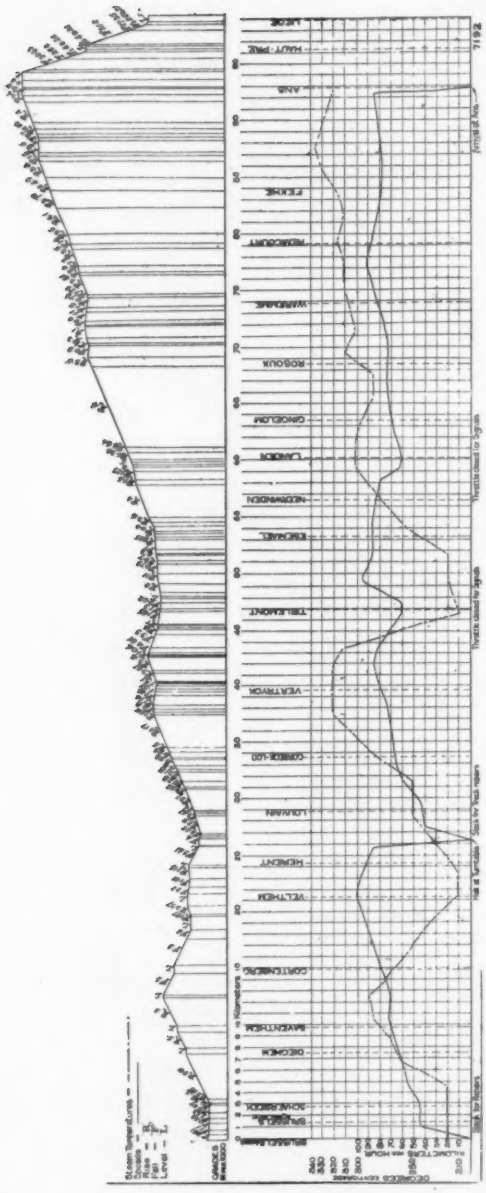


FIG. 15.—A RUN BETWEEN BRUSSELS AND AMS WITH A 4-CYLINDER SINGLE EXPANSION LOCOMOTIVE, "LA MEUSE," FITTED WITH "BELGIAN-STATE" SUPERHEATER. DIAGRAM OF SPEEDS, GRADIENTS AND STEAM TEMPERATURES. LOAD HAULED, 327½ TONS.

in the writer's opinion, to be regretted that enterprising railway companies at home should be content to import only one type of continental locomotive (the advantages of which he was the first to mention in English literature), but which no longer holds the first place for construction, for maintenance, or for economy among modern locomotives.

Starting valves, intercepting valves, or change valves have been such a source of trouble with compound locomotives, that every designer has endeavoured to get rid of them; notably so, Goelsdorf, Lindner and others. In the Exhibition all de Glehn locomotives are fitted with the de Glehn change-valve, worked by assistant-motors. Even the Est compound system now comprises this valve, which is certainly one of the best. The P. L. M. tried it for a time, but found no valve at all was better still. The solution was simple, and one that is very well known in Austria. It consisted, in engines having neighbouring cranks set at 180 deg., of giving a very long cut-off to the high pressure valves (90 per cent. of the piston stroke) for starting purposes. This then gives the requisite turning effort for engines starting with cranks however they present themselves. Live steam from the boiler can be admitted for an instant in the receiver in exceptional cases of necessity. In many countries this supplementary

admission is made automatic beyond a certain degree of cut-off for the high pressure valves, and this by a simple mechanical connection with the reverse gear. In the new Belgian compounds this admission is automatically effected by a small valve with differential pistons, which allows steam from the boiler to leak into the low pressure valve chests so long as the pressure there remains below 88 lbs., but above which it ceases to act. The driver may stop this automatic action at any time by means of a small lever under his control. In fact, in all countries, except France, the object striven for is always to make the handling of a compound engine identical with single expansion engines.

Considered as carriages, there are many details to note in the locomotives shown at Liège. The bogies are usually of the common type, with traversing-pin direct lateral displacement. This is good for four-coupled engines, but rather stiff for engines with a long rigid wheelbase as the six-connected type. The new bogie trucks of the Belgian State Railways destined for all the six-coupled four-cylinder engines, as also for locomotives of the de Glehn model, are of the swing bolster type, without lateral check springs. The pivot is hemispherical. Side rolling of the engine on its truck is permitted within the limits arranged in a pair of side rests, one on each side of the bogie frame, containing vertically-placed helical springs, as adopted a few years back in Hungarian express locomotives.

Another supple arrangement with no rigid side rests is that employed by the P. L. M., and shown in Fig. 10. The bogie pivot is spherical. It is carried in double inclined planes, and not only allows lateral displacements in the box containing it, but on curves the engine is tilted to the inside of the curve. One more flexible truck is that beneath the front end of the eight-coupled de Glehn goods engine of the Midi railway. This is of the swing type shown in Fig. 11. The truck is two-wheeled, Bissel type, and is of interesting construction.

In France bogie frames nearly always have deep plate sides with a spring for each wheel, as in all the new four-cylinder Belgian engines also. The exceptions, approaching English types, are to be seen in the P. L. M. and Ouest locomotives (Figs. 1, 10, and 12). Direct acting air brakes are applied to all wheels of the bogie of most of the French locomotives and of all Belgian State locomotives, following, therefore, the lead of Central Europe.

In general equipment, it may be noted that steam reversing gears are very extensively applied to Belgian locomotives of all types, and the driver is now stationed at the left-hand side (that is, platform side). An example of this is shown in Fig. 13 of a new type single expansion superheating locomotive for heavy passenger service. The inside cylinders of most of the new Belgian engines are so large that the frames have to be slotted out to make room for them (see Fig. 13). Klotz-Wilson safety valves, reaching down towards water level, are fitted in duplicate to nearly all Belgian locomotives. Balanced regulator valves are employed (see Fig. 2). The blast nozzles are usually fixed, but the French are of variable double-wing pattern. The P. L. M. has, however, just introduced a variable annular nozzle (see Fig. 10), and the Nord shows a specimen of a new annular nozzle applied to its 16-wheeled duplex compound locomotive (Fig. 14). Longitudinally-forked blast pipes are used in the Est engines (Fig. 5), and in one of the Belgian engines (Fig. 2). The exhaust from the valve-chest ends is thus made more directly to the air, avoiding back pressure.

In the construction of locomotives, steel castings are daily replacing, more and more, forged pieces. The Belgian State has recently given builders a long list of parts at present forged, which they can replace at will by steel castings. In Hungary foundation rings are steel castings, and in Germany bar frames have been cast of steel. At Liège, the Cockerill compound engines (Fig. 8) have steel castings guide-bars for crossheads, but the most remarkable example

in steel castings is the duplex compound goods locomotive of the Nord (Fig. 14). Here guide-bars, cross-heads, cross-head brackets (for lead-lever motion), cylinder caissons and frame braces, "stretchers," smoke-box saddle, buffers (with oblong faces), and buffer brackets are, together with brake-beams and a number of lesser parts, all of steel castings. It is, of course, not necessarily a cheap engine that is built of steel castings, but it may be, and generally is, much lighter than if forgings had been used.

This engine differs from Meyer type articulated locomotives in having its two motor trucks quite independent, and also by the introduction of a box-girder frame (extending from end to end of the engine) secured to the boiler. It takes all strains of traction and of buffing, consequently it can pull a thousand tons with either end leading, while this would be impracticable had that strain to be borne by the leading bogie truck. The motor trucks take no traction strains except through their pivots. The rear coal bunkers and tanks are solid with the superstructure; the front tanks are carried on the front bogie. This type of engine is designed for fast coal haulage between Lens and Paris *via* Busigny and Hirson in mounting certain grades of 12 per 1,000. Already in the first trials, the machine No. 6,122 has pulled trains of 800 metric tons up long inclines of 13 per 1,000, at 20 kilms. per hour, and runs with perfect steadiness at 75 kilms. per hour.

The results obtained from one of the Belgian superheating engines, "La Meuse" (Figs. 6 and 7), are graphically shown in the diagram (Fig. 15). The variations of temperature are in part attributable to the inexperience of the driver—a novice in superheating. The engine picks up five minutes over this difficult route, and replaces two locomotives of the "Caledonian" model, which have each a tractive effort of 13,300 lbs. against 25,000 lbs. of the "La Meuse."

This diagram shows the remarkable effect of high superheat in maintaining speed whilst ascending heavy inclines, and just when there would be a drop in the velocity with most saturated-steam locomotives.

In conclusion, the lesson which the writer draws from the remarkable advances, made in one bound, for increasing the efficiency and power of steam locomotives, as illustrated by the examples shown at Liège by the Belgian State Railway, is this, that if within so short a period all other railway companies made improvements of corresponding magnitude, then the mechanical efficiency of the steam locomotive would tend rapidly to equal the output of energy recorded with some recent electro-locomotors employed for pulling railway trains. At present the best-designed locomotive in Europe only pulls, in express services, five tons for each ton of its own average working weight. The electro-locomotor, at equal speed, draws a little more. But where is the logic of comparing a power generator to a means of transmission? The electro-locomotor is to the locomotive what a fly-wheel belt is to a steam engine—no more. That the means of such transmission amounts to a luxury no one will deny—suburban service proves it. But the steam locomotive can, and will be, made a better heat engine, for it is capable of immense improvement, and can be designed to work with an absence of disturbing forces practically equalling the electro-locomotor.

* NOTE.—*The Motion Diagrams referred to on pages 312—315 are unavoidably held over until the next issue.*

House Drainage.*

By GERARD J. G. JENSEN.

Sanitary Fittings.

THE concluding object to be considered, viz., the provision of thoroughly *sanitary* fittings, is one requiring all the more careful attention from the fact that the majority of these apparatus are fixed within the house and are therefore in direct aerial communication with the interior of the dwelling. Their construction, design, arrangement and connection to the drainage system must therefore be such as to leave no doubt as to their efficiency and cleanliness, if health is to be maintained.

The subject of these appliances embraces such a wide field that it is impossible to treat with them in any detail in the present instance, and such remarks as can here be made regarding them must necessarily be of a more or less superficial and general nature.

The qualities necessary in all sanitary appliances are simplicity, durability, efficiency in that which is required of them, and, as far as possible, self-cleanliness. To attain the last-named, the appliances must be designed and constructed in such a way and of such materials that the retention of filth—be it by absorption or deposit—is impossible. They must also, as far as practicable, be void of mechanism, which is at all times liable to deteriorate or go wrong, and, above all, to collect dirt. All portions of the apparatus must, moreover, be accessible for cleansing by hand when necessary, and such cleansing must be made easy, and its necessity apparent, in order that it may not be neglected by the householder.

All sanitary fittings, it need hardly be said, must be fixed in well-lighted and efficiently-ventilated apartments, and should preferably be fixed against outside walls, so that their waste pipes may be shortened as much as possible and taken into the external air immediately. They should also, as far as practicable, be fixed free from the floor and walls of the rooms, in order that all their external surfaces may be get-at-able for cleansing. Casings should be avoided, as these only too frequently serve as a last resting place for old boots, worn-out house-flannels, scrubbing brushes, and a motley assortment of similar articles which do not tend to improve the atmosphere of the house. In the exceptional cases in which casings are really necessary, they should be so arranged and constructed that they may be readily taken down without the use of hammer or screw-driver. Their interior surfaces, no less than the exterior, should also be smooth, and either painted or varnished, in order that they may not absorb moisture and the impurities with which the latter is frequently charged.

The detail which, perhaps, requires the greatest attention in connection with sanitary fittings, and which, in one form or another, is present in almost all apparatus comprised under that heading, is the overflow pipe. However desirable an apparatus may otherwise be, it is not infrequent—it is, in fact, almost a rule—that the overflow arrangement is such as to render it absolutely insanitary. Such is the case with the appliances which overflow through a number of small holes in their sides (as in Fig. 31), or whose overflow pipes are masked by "shells" (as in Fig. 32) or hidden, as in the case of the "secret overflow and waste" arrangement shown in Fig. 33. These overflows are quite inaccessible, and, being speedily covered

* Continued from page 240.

FIG. 31

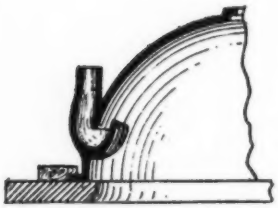


FIG. 32

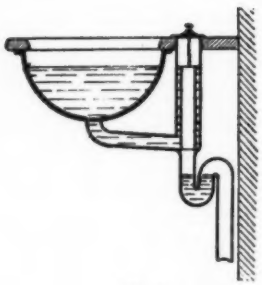


FIG. 33.

on their interior surfaces with decomposing deposits of soap and other organic matter, soon become offensive. Such fittings must, of course, be studiously avoided, and only such made use of in which the overflows are accessible for cleansing by hand, either by the insertion of a brush, as in Fig. 34, or by being provided with a detachable overflow as in Fig. 35. Lavatories, baths, and sinks, with self-cleansing overflows, are now also available. In general appearance these overflows are not unlike that shown in the last-named illustration, but whereas that is *lifted up* from the outlet, the self-cleansing overflows are partly *pushed into* the waste pipes. Consequently, a portion of the waste water must necessarily pass out into the waste pipes through the overflow pipes, which thus receive a thorough flush, both in their interior and on their exterior, whenever the fittings are used.

Whatever the form or type of overflow, it is essential that it be led to discharge into the upper or inlet side of the trap on the waste pipe, unless—as is required by some water companies—it is made to discharge into the open air. Were the overflow connected to the outlet of the trap, the object of the latter would, obviously, be frustrated, as the waste pipe would then be ventilated into the house by way of the overflow pipe.

As has already been pointed out, each fitting must be trapped separately by means of a suitable syphon trap fixed immediately under the outlet opening. The object of this trap is to exclude from the house any foul air which may be generated by deposits in the waste pipe, and it is, therefore, necessary that it be provided in the case of *all* fittings. Its necessity in connection with baths, sinks and lavatories is

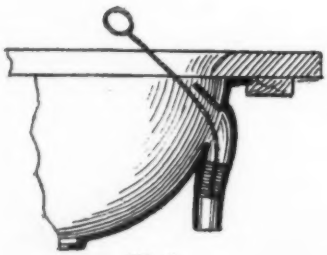


FIG. 34.

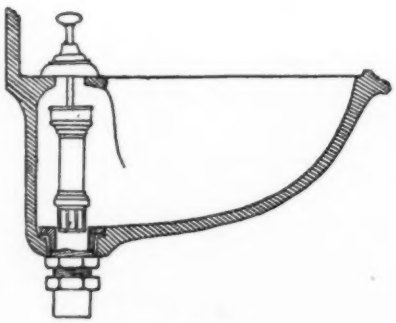


FIG 35.

disputed by many, more especially when the waste pipe upon which it is fixed is but of short length. That the trap is essential, will, however, be manifest to everyone who has experienced the very objectionable smell which invariably issues from a lead pipe lined with even a very thin film of soapy deposit.

Should the diameter of a trap be less than three inches, it is desirable to provide an inspection cap by means of which the trap may be periodically examined and cleaned. For larger-sized traps no such provision need be made, as most parts thereof will be accessible to the hand and arm. It need hardly be said that the sectional areas of traps must in all cases be similar to those of the unobstructed outlets from the fittings upon which they are fixed, and that they should also correspond to the sizes of their waste pipes. As no mention has yet been made of the proper dimensions of waste pipes, &c., it will be convenient to state here that :—

Waste pipes from lavatories should be from $1\frac{1}{4}$. in. to $1\frac{1}{2}$ in. in diameter; waste pipes from pantry sinks should be from $1\frac{1}{4}$ in. to $1\frac{1}{2}$ in. in diameter; waste pipes from scullery sinks should be from $1\frac{1}{2}$ in. to 2 in. in diameter; waste pipes from baths should be from $1\frac{1}{2}$ in. to 2 in. in diameter; soil pipes from water closets should be from 3 in. to 4 in. in diameter; soil pipes from slop-hoppers should be from 3 in. to $3\frac{1}{2}$ in. in diameter; soil pipes from urinals should be from $1\frac{1}{2}$ in. to 2 in. in diameter.

The diameters of ventilation pipes must of course correspond to the dimensions of the drains or pipes which they are to ventilate.

Sufficient reference has already been made to the treatment and construction of the various outfall pipes from sanitary fittings, under the headings of secondary disconnection, ventilation, and materials, and there is therefore no occasion to weary the reader by again discussing the subject.

In conclusion, it may be well to lay stress upon the necessity for examining and testing the drains of every building, not only at the time of construction, but also at regular intervals subsequently—at least once yearly—as even the best constructed system of drainage is apt to deteriorate or go wrong through unforseen causes. For the purpose of ascertaining the absolute soundness of the drainage, the water, compressed air, and, in some few cases, smoke tests are the only reliable tests. All others may be placed in the same category as the verbal assurances of sanitary soundness given by builders and house agents.

Internal Combustion Engines.—II.*

By DUGALD CLERK, M.Inst.C.E.

In considering the indicator diagrams obtained from actual engines, it is necessary to remember that the operations of the ideal engines which I have briefly discussed in my first lecture, are not followed in many respects. The actual engines differ from the ideal ones in many ways. Following the cycle of operations as it occurs in a constant volume engine:

(1) The working fluid generally gains some heat on entering the cylinder at a time when it would be better for the temperature to remain at its lowest point.

(2) During compression, the line followed is not quite adiabatic. There is a certain amount of heat loss going on to the sides of the cylinder after a certain part of the stroke is completed.

(3) The supply of heat is never added instantaneously as required in this type. Naturally the spread of the flame takes some time, although undoubtedly that time is very short. The time taken, however, depends upon many circumstances, some of which we shall consider.

(4) During the expansion stroke, after heat has been added, considerable heat loss occurs to enclosing walls and to the end of the piston.

(5) The working fluid does not behave as a perfect gas. Owing to the complex phenomena of combustion its physical state is changed to some extent during the addition of heat; that is, while we compress one working fluid, viz., a mixture of inflammable vapour and air, we expand another working fluid, viz., a mixture of nitrogen, some oxygen, and products of combustion.

(6) The admission, transfer and expulsion of the working fluid are not accomplished without some resistance—throttling during admission and back pressure during exhaust. On the charging stroke the losses are of two kinds, both of which tend to reduce the charge weight admitted to the cylinder. The mechanical loss is due to throttling at admission, and the physical loss is due to heating of the charge as it enters the cylinder. It is the object of the engine designer to get the greatest possible weight of charge into the cylinder per stroke, so as to obtain the maximum power for given dimensions. Throttling during admission causes loss by resistance to the movement of the piston, but this loss is trifling. In a well-designed engine, it does not usually exceed from 1·5 to 2 lbs. per sq. in. Such a loss is between 2 per cent. and 3 per cent. of the indicated power, and so far as resistance to engine movement is concerned, slight variations are of little importance. This point, however, requires careful attention for another reason: the effect of throttle on charge weight is very material. Assume atmospheric pressure to be 15 lbs. per sq. in., then a deficit of 1·5 lbs. means reduction of charge weight by 10 per cent; 3 lbs. reduction by 20 per cent. That is, in a given engine with certain permissible limits of maximum temperature, the power would be reduced by 10 per cent. by the first imperfect filling, and 20 per cent. by the second. It is therefore of great importance to secure the proper filling up of the cylinder to atmosphere at the out end of the stroke. This is secured in the best gas engines by holding the inlet valves open considerably after the crank crosses its out centre. In many engines running at fair piston speeds the inlet valve does not completely close till the crank has passed from 30 deg. to 40 deg. under the centre. As the cams of modern engines are all of the trailing type, so as to secure quiet seating, this results in the valve being well open at the end of the stroke, and practically closed before the piston returns materially.

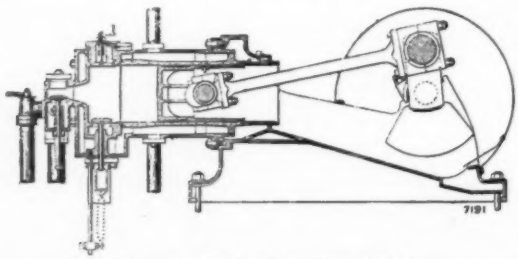


FIG. 7.—VERTICAL SECTION OF NATIONAL GAS ENGINE.
Type "X"; diameter of cylinder, 14 ins; stroke, 22 ins.; B H.P., 68

Continued from p. 258.

To obtain the best result, it is necessary to keep the charge velocity through the inlet valve low and have the air and gas passages as direct as possible. A very usual mean charge velocity is 80 ft. per second. To secure this free charging, the inlet valve also opens before the termination of the exhaust stroke—30 per cent. is usual—and for another reason the exhaust and charging valve are often open together. The effect of throttling in reducing the power of the engine is the same as that found in engines working up among the mountains. Assuming barometric pressure at the sea level to be 30 ins. of mercury, then at 3,000 ft. up the pressure would be about 27 ins., so that the engine would lose 10 per cent. of its power. This loss is analogous to loss due to throttle.

So much for the mechanical loss. The heating loss acts in the same direction. Gas engines of moderate dimensions, say up to 18 ins. cylinder diameter, are found to give maximum economy when the water jacket is somewhat warm, usually about 80° C. Working in this condition at nearly full load, the piston end gets somewhat hot, something like 400° C. in an engine of small dimensions; and in one so large as 20 inches diameter, something like 700° C. or a dull red in the dark. I am referring of course to ordinary pistons without water jacketing in the piston itself. The exhaust valve also heats to about 400°. When the charge, therefore, enters the cylinder the air and gas supply being at a temperature of, say, 17° C., it comes in contact with walls heated to 80° C., and a piston end and exhaust valve much hotter. This raises the temperature of the charge as it enters, so that when the cylinder is completely charged it is considerably hotter. It is difficult to determine this temperature, but it is very important to know it, not only from the point of view of loss of power, but also from that of pre-ignition. A comparatively small rise in charging temperature will readily produce dangerous pre-ignitions in large engines, and annoying ones in small. Measuring this charge temperature as best one can, it is found that 100° C. is not uncommon. Now a rise from 17° C. to 100° C. reduces the charge weight, and therefore the engine power, from 1·0 to 0·775; that is, it reduces the power by 22·5 per cent. Thus we see that for every degree Centigrade rise above

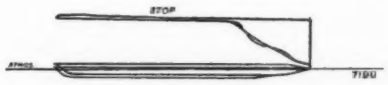


FIG. 8.—LIGHT SPRING CARD FROM NATIONAL GAS ENGINE.

17° C., we lose power in the engine by 0·344 per cent.

From the point of view of power alone, it is accordingly very important to keep down the charge temperature, as a loss of 20 per cent. and more is easily incurred in this way. So far, the moral of all this is, if the maximum power is required from the engine, keep everything as cool as possible.

The cylinder has now been charged, and

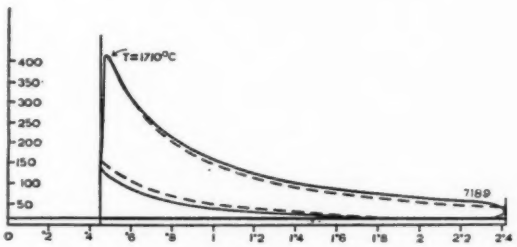


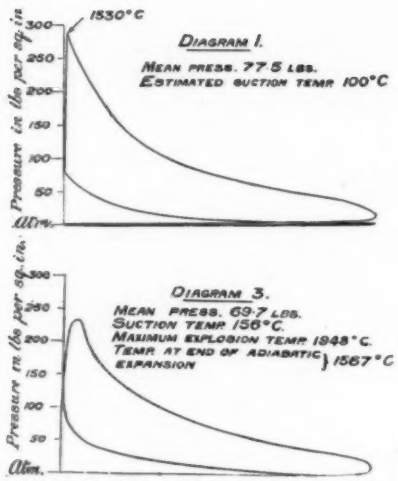
FIG. 9.—HEAVY SPRING CARD FROM NATIONAL GAS ENGINE.

Rich mixture; mean pressure, 94·5 lbs. per sq. in.; 57·5 B.H.P.; maximum temperature, 1,710° C.; exhaust temperature, 1,000° C.; temperature of compression, 440° C.; temperature of charge before compression, 90° C.; indicated efficiency, 33 per cent.; dotted lines adiabatics through points of maximum and minimum temperature, $\gamma = 1{\cdot}408$.

the piston is ready to compress the charge into the combustion space; and here new conditions arise. To get adiabatic compression, there should be the least possible temperature difference between the enclosed charge and the walls. Compressing in a very usual ratio to $\frac{1}{4}$ volume, as shown in several of these diagrams, the temperature would rise from 17° C.—without heat losses—to about 300° C. The mean temperature

FIG. 10.—HEAVY SPRING CARD FROM NATIONAL GAS ENGINE.

Very weak mixture; maximum temperature, 1,250° C.; mean pressure, 85 lbs per sq. in.; indicated efficiency, 29 per cent.



DIAGRAMS 1 AND 2, FROM CROSSLEY TWO-CYLINDER ENGINE.

Cylinders, 18½ in. diameter by 30 in. stroke; average speed, 172 revs. per min.; indicated h.p., 273; brake h.p., 253; indicated thermal efficiency, 30·3 per cent.; test made with Manchester Corporation coal gas, 607·5 B.T.U. per cub. ft., lower heat value. Particulars handed to author by W. J. Crossley, Esq.

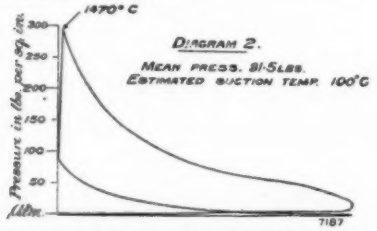


DIAGRAM 3, FROM PROFESSOR BURSTALL'S SECOND REPORT TO THE INST. M.E.; B TRIALS, TEST I.

Engine cylinder, 6 in. diameter by 12 in. stroke; speed about 200 revs. per min.; indicated thermal efficiency, 19 per cent.

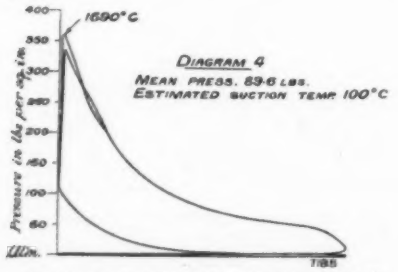


DIAGRAM 4, FROM NATIONAL GAS ENGINE, TESTED BY PROFESSOR ROBINSON.

FIG. II.

of the walls is, of course, lower than this, so on the compression stroke heat losses occur. These would not be serious if the initial temperature had really been 17° C.; but with initial temperature of 100° C. the terminal temperature of adiabatic compression is very much greater; it would rise as high as 470° C. In this case, therefore, there is some loss to the walls. To minimise loss the walls should have approached the temperature more nearly, but that, of course, is impossible, and in this part of the process also the least loss would be found in keeping down wall temperature. Compression being completed, the inflammable mixture is ignited. The time of firing varies with the nature of the gas used; but the object is to make the heat addition as quickly as possible, without causing the pressure to rise so quickly as to produce shock in the engine. With a weak mixture the ignition must be begun early, while the crank is well under the centre, so as to complete the inflammation before the piston has time to make much forward movement. As a rule maximum temperature should be attained before the piston has performed more than $\frac{1}{20}$th of its forward stroke, otherwise the good effect of high compression is to some extent lost. It does not do to ignite too early, however, even to get maximum temperature at the very end of the stroke, as then the hottest flame is exposed for so long a period that the expansion curve falls to a lower point than would otherwise be the case.

The piston now proceeds on the expansion stroke, and the study of the expansion line is of great interest. It is generally stated that this expansion line follows a curve which can be expressed by the equation

$$PV^k = \text{const.}$$

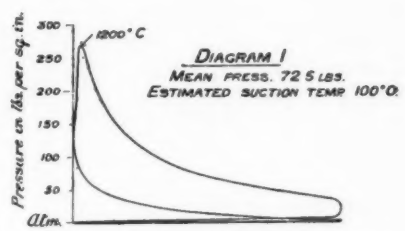
A close investigation of many of these curves, however, shows that this is by no means uniformly true. The expansion curve is in part isothermal, and part no doubt can be expressed in this way; but different parts have varying values of k. It is very important to study this curve thoroughly. To do this, it is desirable to follow the temperature from point to point. To do this easily, I find it a good way to draw an isothermal line from the out end of the stroke, and then to measure the different temperatures in terms of the pressure values on that line, keeping in mind that at every point of the curve temperature is proportional to absolute pressure. When investigating a number of cards, it is convenient to have isothermal temperature scales made so as to read off

temperature at each point of the diagram directly.

The interest of this expansion lies in the fact that further advance is to be found in understanding its message fully; and a very difficult study we find it. One fact, however, emerges clearly: that is, heat is added during the expansion stroke. On this the rival theories are at one. It does not matter whether we adopt the varying specific heat theory, or continued combustion theory, both agree that heat is added. I have observed that many engineers imagine that increasing specific heat at high temperatures does away with the idea of heat additions, because the expanding line becomes an adiabatic, with varying specific heat. But the idea of an adiabatic line with varying specific heat is only another way of saying that the gas is not a perfect gas, but is a substance capable of rendering heat latent, and giving it up again, just like the case of water and steam. A higher constant specific heat does not imply the idea of heat evolution, or absorption; but a variable specific heat does do this. And no doubt it is true that there is some variation of specific heat in the case of high temperature flames, such as those of the gaseous or vapour explosion. Carbonic acid gas cannot be far from its dissociating point, and no doubt specific heat increases to some extent because of that. This appears to be proved by Professor Harold Dixon's experiments.* Steam also may be near its dissociation point, although not so near as CO_2. This, however, by no means accounts for all the phenomena of heat suppression, because at low temperatures there is as great a heat suppression as at high; and this of course could not be so if increasing specific heat furnished the whole explanation. All are agreed on two things, then: that heat is added in the expansion curve, as well as on the rising temperature curve. They differ on the explanation, but all admit the fact.

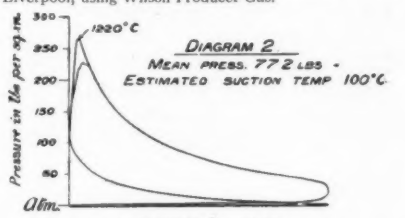
The cycle is completed by the opening of the exhaust valve, and the expulsion of the products of combustion. This should of course be done with as little resistance as possible. Mean velocity of exhaust in a good engine will be about 70 ft. per second. To furnish the data required for the careful study of a diagram, it is necessary to determine the following principal quantities, in addition to taking diagrams:—Brake power, indicated power, gas consumption, air consumption, heat flow through jacket, radiation from engine, heat

* See ENGINEERING REVIEW, vol. xi., pp. 143—147.



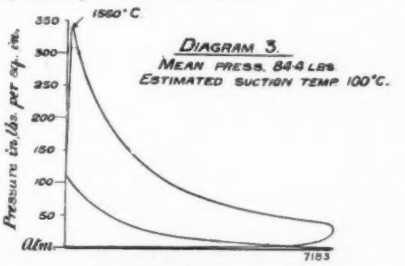
"STOCKPORT" ENGINE.

Cylinder, 20 in. diameter by 27 in. stroke; speed, 182 revs. per min.; indicated h.p. 141; at Musker & Co.'s, Liverpool, using Wilson Producer Gas.



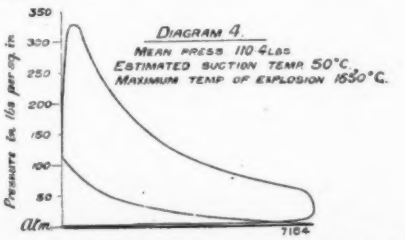
"STOCKPORT" ENGINE.

Cylinder, 18 in. diameter by 27 in. stroke; average speed, 180; indicated h.p. 113; at Musker & Co.'s, Ltd., Liverpool, using Wilson Producer Gas. Diagrams 1 and 2 and particulars of test have been supplied to the author by Messrs. J. E. Andrew & Co., Ltd.



"NATIONAL" GAS ENGINE.

Brake, 40 h.p.; speed, 170 revs. per min., giving brake 32 h.p. at time of test; four explosions and one cut-out; engine at Dowson's Works, Basingstoke, with Dowson suction gas plant using anthracite. Diagram taken by the author.



"PREMIER" GAS ENGINE AT WINNINGTON, TWO CYLINDERS.

FIG. 12.

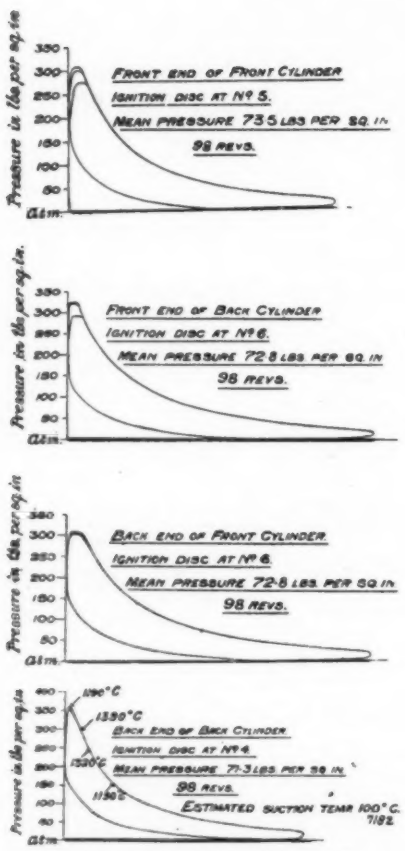

Pressure in lbs per sq in
FRONT END OF FRONT CYLINDER
IGNITION DISC AT Nº 5.
MEAN PRESSURE 73.5 LBS PER SQ. IN.
98 REVS.
Pressure in lbs per sq in.
FRONT END OF BACK CYLINDER
IGNITION DISC AT Nº 6.
MEAN PRESSURE 72.8 LBS PER SQ IN
98 REVS.
Pressure in lbs per sq in.
BACK END OF FRONT CYLINDER
IGNITION DISC AT Nº 6.
MEAN PRESSURE 72.8 LBS PER SQ IN.
98 REVS.
Pressure in lbs per sq in
1190°C
1330°C
BACK END OF BACK CYLINDER
IGNITION DISC AT Nº 4.
1330°C
MEAN PRESSURE 71.3 LBS PER SQ IN.
98 REVS.
1150°C
ESTIMATED SUCTION TEMP 100°C.
7182

FIG. 13.—GAS ENGINE (COCHRANE, NO. 250).

carried away by exhaust gases, heat value of gas, engine dimensions, clearance space.

I will now consider diagrams taken by myself in tests recently made with a National gas engine, called by the National Company "X" type, having a cylinder diameter of 14 ins., and a stroke of 22 ins. The engine is shown in the section, Fig. 7.

Fig. 8 is a light spring card from the engine, to show the resistance to charge and discharge. In all engine tests, these light spring cards are taken with a spring having a strength of about 10 lbs. to the inch upon the diagram. They are necessary, as it is otherwise impossible to distinguish clearly what is going on when a heavy spring is in the indicator for the purpose of taking explosion and expansion pressures. From this diagram it will be seen that the piston on its forward stroke draws in a charge which reduces the pressure to about 1½ lbs. below atmosphere. This is a resistance. At the end of a stroke the cylinder fills up while the piston is crossing the centre, and the cylinder is thus nearly fully charged with a mixture of gas and air. This filling up of the cylinder is very important, as a very small defect of pressure at the charging end of the stroke greatly reduces the power of the engine. All the good engine designers hold open the charging valve while the crank is crossing the centre at the out end of the stroke, so as to enable the pressure to rise as nearly as possible to atmosphere before compression begins. It is accordingly very important, when inspecting a light spring card, to note whether the cylinder is well filled or not. The object of the designer is to cause the cylinder to fill entirely up to atmospheric pressure before the piston returns on its compressing stroke. The light spring card also shows a line above the atmospheric line, the higher pressure being due to the resistance of the exhaust gases. The mean back pressure from this cause is something like 2 lbs. on the square inch. It is an interesting fact that when an engine is governing in the commonest English method—that is, by cutting out impulses—the discharge stroke of the cold air always shows a greater back pressure than that of the hot exhaust. This is due in part to the heavier weight which must be moved by the piston, when the gas to be discharged is cold, and in part to the fact that a vacuum wave is caused in the exhaust pipe of a gas engine by the act of discharging the exhaust from a pressure above atmosphere. So far as the light spring card is concerned, the two main points to be noted are the resistance on the suction stroke, and the terminal pressure before compression. Further, the freedom of the exhaust discharge is also to be noted, although that may vary to a greater extent than the charging resistance, without causing serious loss in the operation of the engine.

Fig. 9 shows an indicator card taken with a heavy spring. In it is seen a slightly thickened line, about the atmospheric line. This is all that is shown of the suction and exhaust resistance, because of the very powerful spring necessary to resist the explosion pressure. This card is used to follow the compression, the ignition, the expansion, and the first part of the exhaust—that which falls from the terminal expansion pressure to the atmosphere.

Looking at this card, in the light of experience of many diagrams, it becomes obvious that the mixture here has been slightly too strong. The result is distinctly economical, but it is not so economical as the result with a slightly weaker charge. Under the diagram are marked the various particulars of the test made at the time at which the diagram was taken. Upon this diagram I have shown the clearance space of the engine, and I have calculated and plotted upon the diagram the adiabatic expansion line from the point of minimum temperature. I have also dotted above the main compression line the adiabatic line which would be followed if no heat loss occurred during compression. From these dotted lines it will be seen that whereas the compression line falls slightly under the adiabatic, the expansion line keeps somewhat above it.

Taking this card, and calculating the heat evolved, the heat accounted for at the point of maximum temperature, I find that altogether some 70 per cent. of the total heat of combustion appears to have been evolved at that point; or, putting it in accordance with the idea of the French physicists, the specific heat of the charge has increased at the high temperatures, and so, although the whole heat is evolved, it cannot produce the effect in increasing the pressure which would be produced had specific heat remained constant. The temperatures at the principal points are given below the diagram; and here it is necessary to explain that some difficulty arises in calculating these temperatures. This difficulty is one which does not depend upon the question of combustion or no combustion, but is a purely experimental one. As you are aware, in order to calculate the temperatures on every part of this diagram, it is necessary to know the temperature at some one point with some accuracy, or to know the total weight of charge contained within the cylinder just before compression commences. In ordinary tests it is difficult to determine the volume of air taken into the engine, and all that we usually know is the volume of gas used for a given number of strokes, and the volume swept by the piston during its operations. If we knew the weight of charge entering the engine, including the weight of the exhaust gases remaining in the combustion space at the exhaust end of the stroke, then all the temperatures on this diagram could be calculated with ease and certainty.

In the ordinary running of an engine of this type, at anything like full load, it is

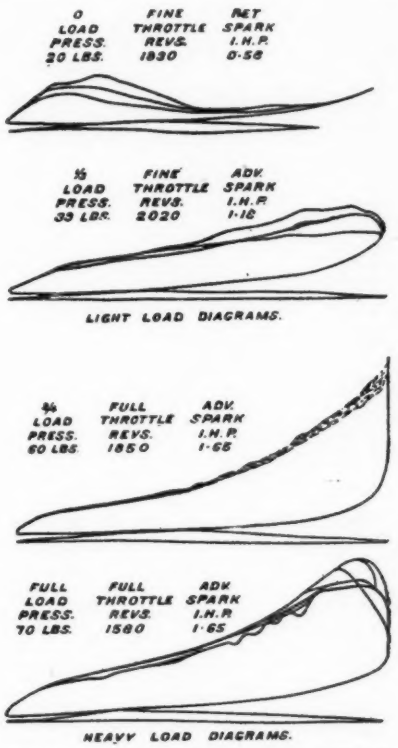

0 LOAD PRESS. 20 LBS.
FINE THROTTLE REVS. 1830
RET SPARK I.H.P. 0·58
½ LOAD PRESS. 35 LBS.
FINE THROTTLE REVS. 2020
ADV. SPARK I.H.P. 1·18
LIGHT LOAD DIAGRAMS.
¾ LOAD PRESS. 60 LBS.
FULL THROTTLE REVS. 1850
ADV. SPARK I.H.P. 1·68
FULL LOAD PRESS. 70 LBS.
FULL THROTTLE REVS. 1580
ADV. SPARK I.H.P. 1·65
HEAVY LOAD DIAGRAMS.

FIG. 14.—DIAGRAMS FROM PETROL ENGINE, TAKEN BY PROFESSOR CALLENDAR.

found that the best water jacket temperature is somewhere in the neighbourhood of 80° C., that is, the water jacket, which is seen in Fig. 7, for keeping the cylinder and combustion space cool, is best so arranged that the cylinder is maintained at this temperature. Under these circumstances, in such an engine as this, the piston end, of course, attains a much higher temperature, and it becomes difficult to estimate what is the exact temperature of the charge as it enters. Assume the air and gas to be entering at atmospheric pressure and temperature, say 17° C., then it is obvious that the charge becomes heated as it passes into the cylinder. The entering gases impinge upon the hot walls upon the hot piston, and so they become heated. They also become heated to some extent by mixing with the exhaust gases remaining from the previous explosion, in the combustion space of the engine. The question

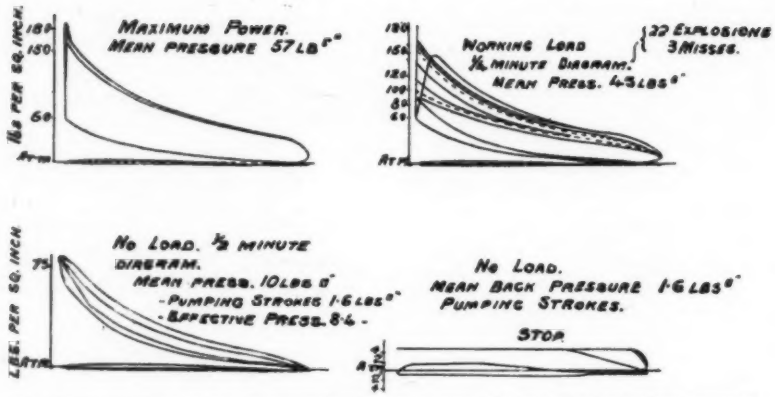


FIG. 15.—DIAGRAM FROM 25 H.-P. "HORNSBY" HEAVY OIL ENGINE, 1898. TAKEN BY PROFESSOR ROBINSON.

of the heat given by these exhaust gases, and the heat given to the walls, is one which it is necessary to solve, in order to know the exact temperature of the incoming charge. In these particular experiments, the air supplying the engine was measured. This determination enables me to give not only the volume of air and gas admitted to the cylinder, but also the volume of air. The only question remaining, therefore, is the weight of the exhaust gas left. This has been determined by several experimenters, and recently the question has been carefully gone into by the Thermodynamic Standard Committee of the Institution of Civil Engineers. The charge temperature on this diagram, determined as nearly as possible, amounts to 90° C. Assuming then this to be the temperature of the charge before compression, the temperature in the different parts of the diagram have been calculated by well-known formulæ. Comparing these figures with those on the ideal card for the same clearance, it appears that the expansion curve shown here is somewhat above the adiabatic. This, of course, means that in some way heat has been added on the expansion stroke, either by change of specific heat or by continued combustion, so as to make up for the loss passing through the cylinder sides In this particular test the heat distribution is approximately as follows:—

Indicated work	33·1	57·5 B.H.-P.
Jacket loss	36·0	
Radiation	6·0	
Exhaust loss	42·0	
	107·1	

This method of determining the disposition of the heat should always overbalance. The reason for this is that part of the heat set down as exhaust loss does not really get away from the engine. The hot exhaust gases impinge on the surfaces of the valve boxes and exhaust passage, and thus give up part of their heat to the engine and water jacket. This heat is thus taken into account, both under the head of jacket loss and as exhaust loss. Part of the loss set down as exhaust loss is also given back to the engine as heat given to the incoming gases.

Here we have a very good efficiency, 33 per cent. for the indicator, and ·28 per cent. for the brake; but this is not the best result which the engine can give.

The efficiency may be improved by slightly throttling the gas, so as to give a smaller gas supply. The ignition would then take a longer time, and the upper part of the explosion curve on the diagram would be gently rounded, the maximum temperature being considerably, and the mean pressure slightly, reduced. An indicated efficiency of 35 per cent. may thus be obtained with this engine.

Fig. 10 shows another card, or series of cards, where the dilution has been carried to an extreme. The effect here is to cause the engine to run, not quite, but almost as a constant pressure engine. Considerable reductions in maximum temperature and mean pressure, however, are noted; but the economy falls off considerably. It is 25 per cent. Bk. E. and 29 per cent. I.E. Here the consumption has risen from the best point, which is slightly less than that

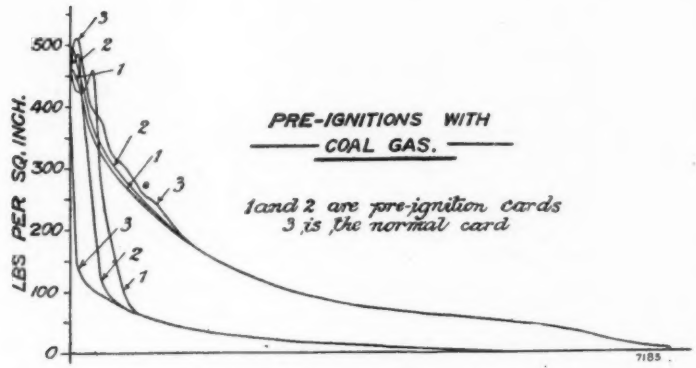


FIG. 16.—DIAGRAM FROM "NATIONAL" HEAVY OIL ENGINE; OIL CONSUMPTION, ·735 LBS. PER B.H.-P. HOUR.

shown in Fig. 9, to about 18 cubic feet per B.H.-P. per hour, and the power has fallen by more than a third, to 38 B.H.-P. These diagrams illustrate the range within which economy may be found. The first diagram corresponds to some extent to what in the steam engine would be known as an over-load diagram; slightly less gas would give a diagram of maximum economy; and the diagram (Fig. 10) shows a case where the mixture has been purposely over-diluted. Although the ignition is too late, and consequently the cycle becomes rather a constant pressure than a constant volume cycle, yet the absolute heat loss through the sides of the cylinder is considerably reduced, the relative loss remaining about the same.

Comparing the efficiencies obtained with a normal gas supply with the standard air engine efficiency given for the same clearance space in the last lecture, you see that the efficiency in the actual cycle ranges from ·6 to ·7 of the ideal. These diagrams are taken with coal gas.

Figs. 11—16 show a number of diagrams taken from various engines with different gases. Comparing the diagrams you will see that generally the coal gas explosions show fairly sharp rises, as in the Crossley and National engines, while the producer gas explosions generally, though not always, show a gentler rise, and a more indefinite maximum point. Many makers use somewhat higher compressions for producer gas than for coal gas, and when blast furnace gas is used, still higher compressions are adopted. This you can see by looking at Fig. 16, where the compression pressure has risen to nearly 150 lbs. in one case.

The petrol engine diagrams (see Fig. 17) were taken by Professor Callender with a very small air-cooled bicycle motor.

Fig. 15 shows diagrams from the well-known Hornsby engine, taken by Professor Robinson; and Fig. 16, similar diagrams from a heavy oil engine by the National Gas Engine Co.

Very varying compressions are used, and the appearance of the diagrams vary to a considerable extent. In all these engines however, if the compression space be known, and the efficiency be calculated from the formulæ for constant volume engines using air without heat losses, and that efficiency

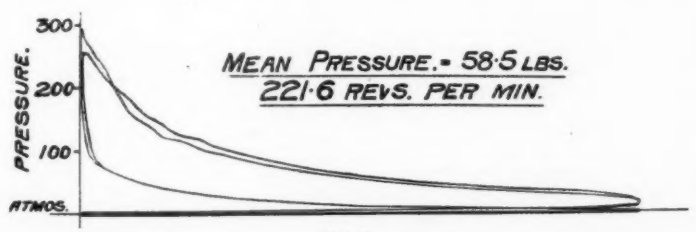


FIG. 17.

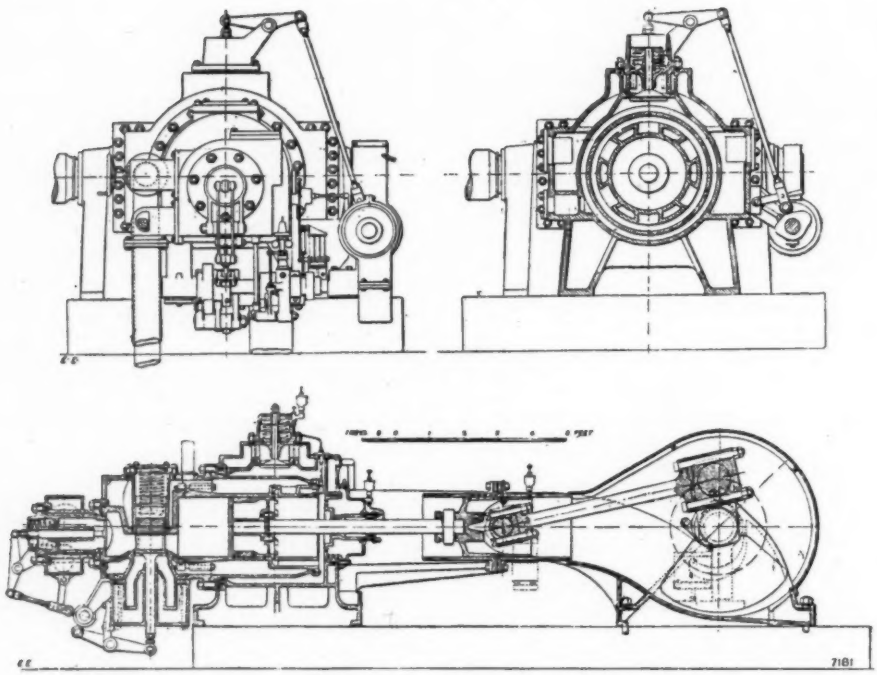


FIG. 18.—"NATIONAL" AIR COMPRESSION ENGINE.

multiplied by a factor between ·6 and ·7, the practical efficiency of the engine will be at once given.

On the adiabatic compression curve shown in Figs. 5 and 6 I have marked temperature and degrees Centigrade at various stages of compression. A consideration of these temperatures will make evident the reason for certain limits to increasing efficiency by increasing the compression. Mixtures of inflammable gas and vapour with air ignite at various temperatures, that is, once a certain temperature is exceeded, the mixture ignites. This igniting point is not very well defined, as a very slow combustion appears to take place in dilute mixtures at quite low temperatures. This has been proved by the investigation of both English and continental chemists.

Many experiments have been made showing that, with certain mixtures of inflammable gases with oxygen or air, exposure may be made to certain temperatures without ignition; but when these temperatures are slightly exceeded the mixtures begin to ignite.

Looking at the adiabatic compression curve shown in Fig. 5 it will be seen that the temperature rises from 17° C., until at the pressure of 500 lbs. per sq. in. it reaches something like 600° C. This assumes that the charge before compression is at a temperature of 17° C. If, however, as is the case in the gas-engine cylinder, the temperature be nearly 100° C., then the temperature with compression to 500 lbs. is very materially increased. It is increased, in fact, in the ratio between the two initial absolute temperatures. With a Diesel oil engine running at full load, compressing to 500 lbs. on the sq. in., the temperature will readily rise to something like 800° C. This is a fair red heat, and this temperature would ignite any inflammable mixture of gas and air.

The problem present to the designer of a constant volume engine is to get as high compression as possible, without exceeding the temperature of ignition of the particular mixture of inflammable gas and vapour to be used in the engine. Although accurate figures have not yet been obtained, yet it is known in a general way that gases which

contain a large proportion of hydrogen are ignited at a comparatively low temperature. With such gases it is accordingly necessary to keep down the compression, if premature ignitions or pre-ignitions are to be avoided. In ordinary practice, with coal gas and air, it is found, for example, that it is unsafe greatly to exceed a compression of one-fifth. If this ratio be exceeded, then any trifling circumstance, such as a spongy place in the piston or combustion space surface, or any little projecting part which can become unduly hot, at once causes frequent pre-ignitions. Pre-ignitions, in fact, are the limiting circumstance which prevents the highest compressions being used in motors of this type.

At Fig. 17 is an indicator card showing a pre-ignition obtained in this engine, due to a spongy part in a tube carrying the indicator. These pre-ignitions, of course, at once reduce the economy of the engine, because they reduce the area of the diagram, and if pre-ignition becomes at all pronounced, the power falls off with great rapidity.

All engineers engaged on gas engine work have to face this difficulty, and various solutions have been advocated. Generally it may be taken that the cooler the incoming charge, the piston, the cylinder, and the combustion chamber can be kept, the less liability is there to pre-ignition. Accordingly, in large gas engines which would otherwise pre-ignite readily, circulating water is very freely used, and the cylinders are kept much cooler than is found to give the maximum economy in smaller engines.

In work in which I have recently been engaged at the National Gas Engine Co., I have designed two types of engine which are intended to meet this difficulty. One of these types, the air super-compression engine (shown at Fig. 18); the other, an exhaust super-compression engine, I have no figure here for, as it is still in the experimental stage. By air super-compression and exhaust super-compression, I mean the addition of air or cold exhaust charge under pressure to the engine charge, and then the compression of the united diluted charge. This addition enables one to get high average pressures with low average temperatures. I have, however, already discussed engines of this type in the James Forrest lecture of last year, and in a paper read before the British Association* in August last, so I need not deal with it here. The exhaust and air super-compression seem to me to enable us greatly to improve the performance of these engines

* Cf. Engineering Review, vol. xi., pp. 298—304.

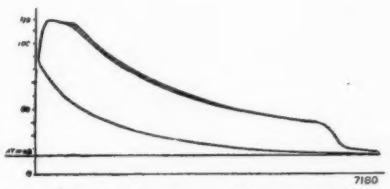


FIG. 19.—DIAGRAM FROM CLERK FLAME ENGINE, 1887.

by working with a motor fluid which is, on the whole, cooler than that given by an ordinary explosion. In my experiments I work at a maximum temperature of not more than 1,200° C., as against the usual maximum temperature of something like 1,600° C. or 1,700° C. Many engines, however, work at fairly low temperatures, such as 1,200° C.; but in such engines the mean pressure is lower than it would have been if some device such as exhaust or air super-compression had been used. The mean pressure indeed is lower by about 20 per cent. than it would have been. Another mode of overcoming this difficulty consists in injection of water into the cylinder during the compression stroke. This I understand is being used by Messrs. Crossley in accordance with a device of Banki.

Whatever device be used, when high compressions are required, it is necessary to look thoroughly to the cooling of every part of the engine, and to the admission of the working fluid at as low a temperature as is possible.

Although the pre-ignition is the greatest of the internal combustion motor difficulties in large engines, there are other troubles which occasionally give considerable annoyance. Sometimes an engine will ignite into the supply pipe. This is called a back ignition. This back ignition is due to the inflammation of the charge as it enters the cylinder by something which it encounters within the cylinder. Sometimes this something is found in the lingering flame from the previous explosion. This is always the case with diagrams like Fig. 10. In these diagrams the combustion rate is so slow that burning charge is still found in the cylinder, even on the beginning of the next suction stroke. The back ignition, however, may also be due occasionally to some incandescent matter within the cylinder, such as burning oil. It may be produced, for instance, by over-lubrication.

Another source of annoyance occasionally found is due to exhaust explosions. An exhaust explosion is caused by the missing of the ignition of the engines and the

discharge of an unburned charge into the exhaust pipe and chamber. On the next ignition stroke the flame discharge through the exhaust valve sometimes ignites the accumulation which has passed into the exhaust pipes, and we hear heavy banging. These troubles, however, back ignitions, exhaust explosions, and missed ignitions, are matters of little moment, compared to the pre-ignitions. They are now well under control. All good gas engines kept in reasonably good order entirely avoid them. All these troubles come in the main from over-heating.

It has often occurred to inventors to avoid all back ignition and other ordinary gas engine troubles by compressing air alone, and adding the inflammable charge just at the moment of completed compression. If this be done, there can of course be no pre-ignition. Pure air cannot ignite, however highly it may be compressed.

In 1887 I had an engine built on this principle, and Fig. 19 is a diagram taken from it. This engine used ordinary coal gas, air alone was compressed in the cylinder, the gas was compressed separately by a side pump forced into the engine cylinder through a series of gas jets, and ignited exactly as it entered. This engine worked very well, but the mean pressures obtained were too low.

Heir Diesel took up the same idea somewhat later, and he endeavoured to apply it to both gas and oil engines. His attempts to apply it to gas engines have so far failed; but he has made a fair success in applying it to the oil engine. The difficulties, however, are very great. Diesel at first thought that he could produce an engine following the Carnot cycle. Ultimately he produced an engine of the constant pressure type, the theory of which follows the diagram shown at Fig. 3.

Locomotive and Railway Notes.

By CHAS. S. LAKE.

New Tank Locomotives for the Rhymney Railway.

THE heavy six-wheels-coupled, radial tank engines, built by Messrs. Robert Stephenson & Co., Ltd., at Darlington, for the Rhymney Railway, were briefly referred to in the Notes for August, and one of their number is illustrated herewith.

The locomotives are powerful examples of their class, and have been designed for performing heavy duty under stringent conditions as to loads and gradients.

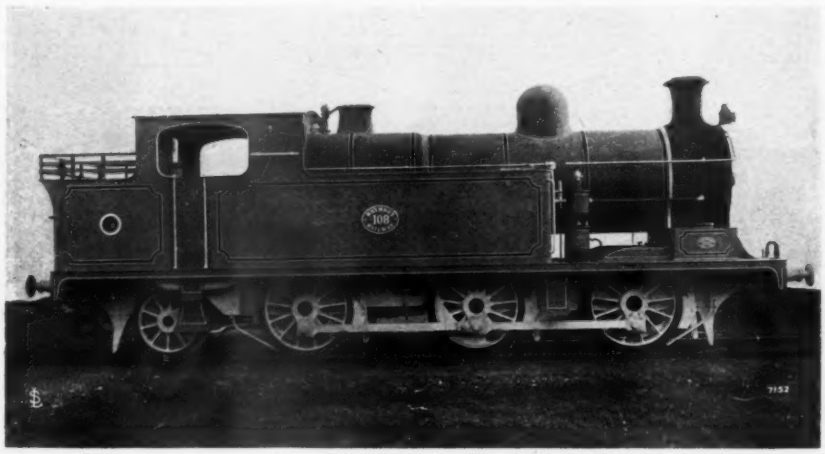
The cylinders, which are 18½ ins. diameter with a piston stroke of 26 ins., are placed inside the frames with the steam chests between them; the slide valves are of the ordinary flat or D pattern, actuated by link motion of the Stephenson type. The boiler, which is of large proportions, is fitted with a Belpaire firebox, the mountings consisting of a steam dome and safety valve of the Ramsbottom type.

A working steam pressure of 165 lbs. per sq. in. is carried, and the total heating surface is 1,374 sq. ft., made up of 1,252 sq. ft. in the tubes and 122 sq. ft. in the firebox; the grate area is 21·5 sq. ft. The coupled wheels have a diameter on tread of 4 ft. 6 ins., and they are distributed over a wheel base of 15 ft. 3 ins. A pair of 3 ft. 6 in. diameter carrying wheels, having radial axle boxes, support the rear end of the engine, the total wheelbase of which is 21 ft. 9 ins. The tanks accommodate 1,400 gallons of water, and the bunker has a capacity of three tons of coal.

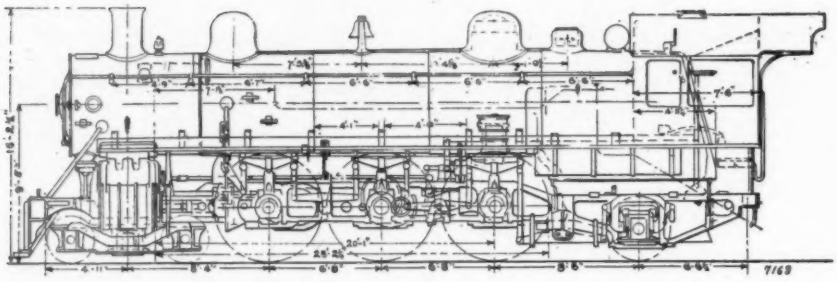
In working order each engine weighs 61 tons 6 cwts., and of this 48 tons 14 cwts. rest upon the coupled axles. From the foregoing particulars it will be seen that these locomotives are among the most powerful of the 0-6-2 type in use upon any of the home railways.

A Recent Development in American Locomotive Engineering.

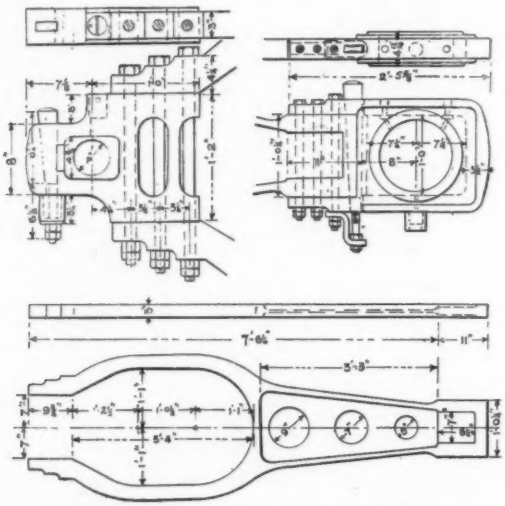
THERE has recently been turned out of the Baldwin Locomotive Works, Philadelphia,



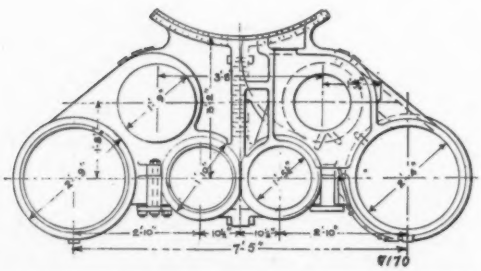
6 WHEELS COUPLED TANK ENGINE FOR THE RHYMNEY RAILWAY.



4-CYLINDER BALANCED COMPOUND EXPRESS LOCOMOTIVE, OREGON RAILROAD AND NAVIGATION CO.



DETAILS OF INSIDE (H.P.) CONNECTING RODS.



ARRANGEMENT OF CYLINDERS AND STEAM CHESTS. 4-CYLINDER BALANCED COMPOUND EXPRESS LOCOMOTIVE, OREGON RAILROAD AND NAVIGATION CO.

the first of a new type of locomotive, having the "Pacific" or 4-6-2 wheel arrangement and four compound cylinders disposed on the Vauclain balanced principle. The design presents many points of interest, and in some respects these are of a unique character, being now tried for the first time in United States locomotive practice.

The cylinders are arranged in line on the bogie centre, with the low pressure outside and the high pressure between the frames, all driving the same axle, viz., that of the intermediate coupled wheels.

This arrangement necessitates the employment of a special design for the inside connecting rods in order that they may clear the axle of the leading coupled wheels. These rods take the form shown in the accompanying drawing, from which it will be seen that they are forked where clearance for the front axle is required, and are generally of unusual design. Each of the two rods was made from a 4,000 lbs. billet, and the finished rod weighs close upon half a ton. The material employed is carbon steel, and very great care was exercised in working out the calculations upon which the design is based. This is the first instance of an American locomotive being fitted with bifurcated main rods, and the practice is of course only indulged in anywhere under conditions rendering it, or some other similar method, obligatory. It may be remembered that Mr. Holden employed this means for overcoming the same difficulty, viz., that of keeping an inside connecting rod clear of a coupled axle, in his ten-wheeled tank engine on the Great Eastern; but the cases are few and far between in which such a feature is resorted to.

The general dimensions of the American locomotive illustrated, and which it should be added is among the largest and heaviest yet put into service, are as follows:—

Cylinders h.p. (2)	17 in. dia.
,, l.p. (2)	28 ,, ,,
Piston stroke	28 in.
Coupled wheels, dia.,	6 ft. 5 in.
Coupled wheelbase	13 ft. 4 in.
Total ,,	33 ft. 7 in.
Boiler dia. smallest ring (out)	5 ft. 10 in.
,, firebox, length and width	9ft. by 5ft. 6 in.
,, tubes, number	245
,, ,, dia.	2¼ in.
,, ,, length	20 ft.
Heating surface, tubes	2,874 sq. ft.
,, ,, firebox	179 ,, ,,
,, ,, total	3,053 ,, ,,
Grate area	49·5 sq. ft.
Working pressure	200 lb.

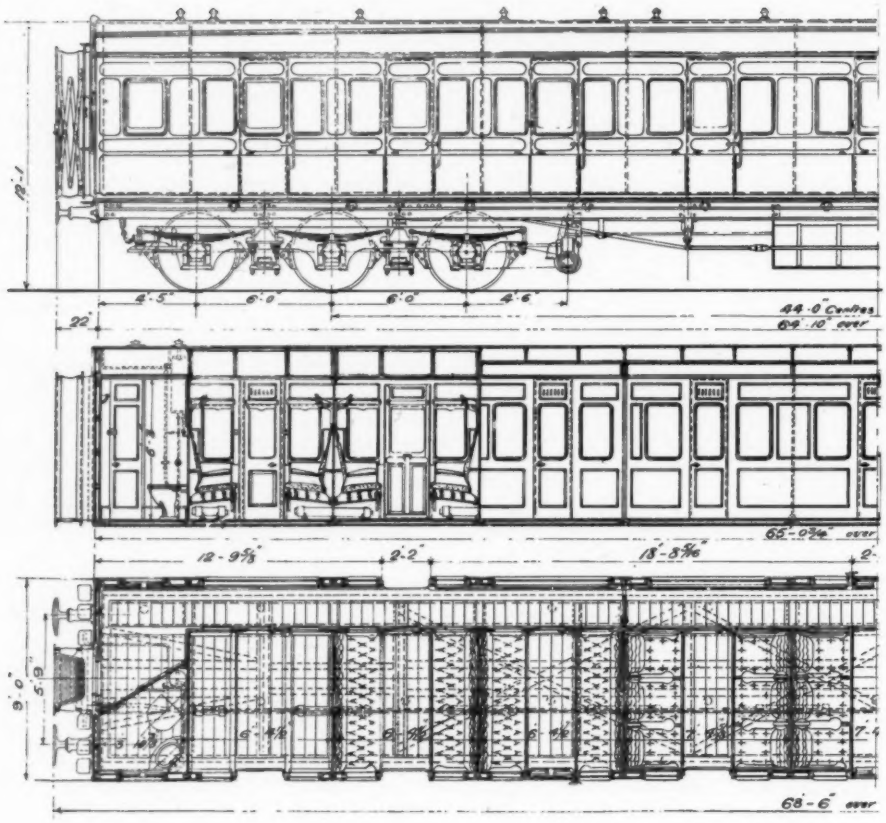
The engine weighs, loaded and without tender, 103¼ tons. The adhesion weight is 64 tons. The tractive power is 28·300 lbs., and the following ratios apply to the design:—

Tractive weight ÷ tractive effort	5·07
Tractive effort × diam. drivers ÷ heating surfaces	713
Heating surface ÷ grate area	61·7
Total weight ÷ tractive effort	8·17

New Railway Bridge in South-West London.

THE new railway bridge across the Thames at Grosvenor Road (L.B. & S.C.R.) has been designed to carry two pairs of rails, providing much-needed extra accommodation for traffic in and out of the Brighton Company's West-End terminus at Victoria; which is itself being enlarged to nearly twice its former size. The bridge has four spans, each of which has a clear opening of 178 feet. There are three piers in the river, built of Swedish granite with a hearting of brindle Staffordshire bricks set in cement; the upper portion being of York stone with a hearting of cement concrete, and the bull-nosed course and skewbacks of Cornish granite.

Cast-iron caissons were employed in connection with the building up of the piers, and of these the two bottom rings remain in position, but the upper portion of each caisson has been removed. The two new roads, one of which is an engine road, and the other an up main line, are each carried by a pair of steel arched ribs hinged at the springings. The hinges have pins of forged steel, 12 in. diameter, with cast steel knuckle castings. Vertical spandril columns are used for transmitting the load to the arched ribs, and these columns are built up of standard sections, with a distributing stringer girder for transmitting the load from the cross girders to the spandril columns. The flooring consists of cross girders and intermediate rail bearers. A stiff bracing connects the four arches of which the bridge is comprised, thus ensuring rigidity, and thorough provision has been made for counteracting the effects of expansion and contraction throughout the entire structure. An approach span occurs at both ends of the bridge, and the line is carried across the extensive goods yard at the south end by means of a number of arches and plate girder spans. In addition to the extra through tracks leading into Victoria, there will be carriage sidings on the southern bank of the river, terminating at the point which marks the commencement of the first span of the bridge on that

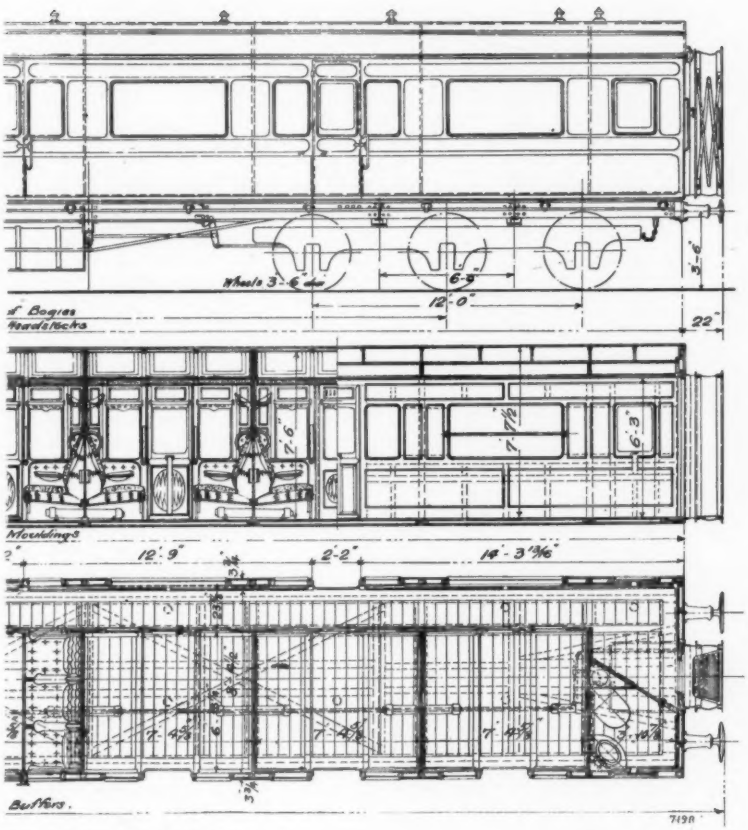


DETAILS OF NEW CORRIDOR

side. A complete re-organisation of methods for working the traffic will come into force when the works have been carried through, when the increased facilities for handling the trains at the terminus, combined with the approved means of access thereto, will enable the company to deal more expeditiously than at present with a far larger volume of traffic, such as may be confidently looked for as a result of the reconstruction scheme, now nearing completion, and which practically involves the whole of the main line between Victoria and Brighton. The writer is indebted to Mr. Charles L. Morgan, M.Inst.C.E., Chief Engineer of the L. B. & S. C. Rly., for the foregoing particulars.

The New Corridor Trains on the Caledonian Railway.

In the spring of the present year, some corridor passenger cars of an improved type were built at the St. Rollox Works of the Caledonian Railway, from the designs of Mr. J. F. McIntosh, Locomotive, Carriage and Wagon Superintendent, to whom the writer is indebted for photographs, drawings, and particulars of the coaches. Two complete trains, each comprised of six cars, of the new pattern, commenced running in April, and a faster schedule was inaugurated, between Edinburgh and Glasgow in the south, and Perth and Aberdeen in the north of the company's system;

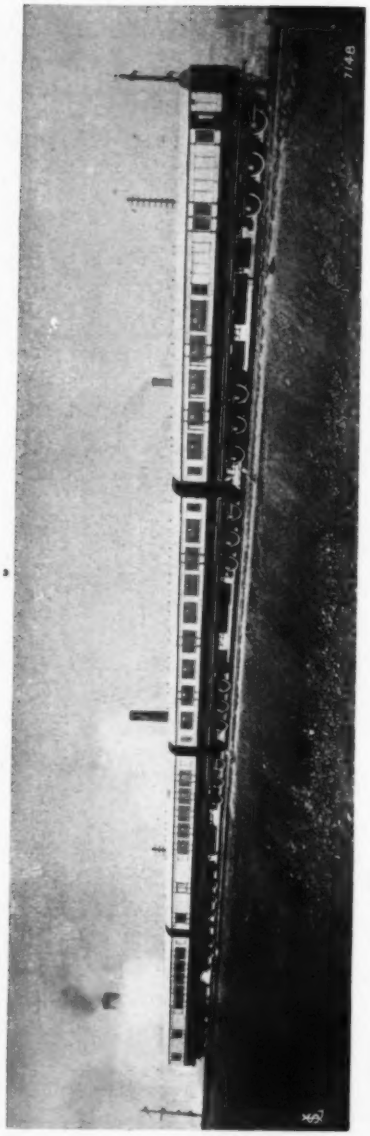


TRAINS, CALEDONIAN RAILWAY.

the train being known as the "Grampian Express," probably for the reason that a splendid view is obtained of the range of mountains so named all the way from Stirling to Aberdeen. In addition to the two trains mentioned, there have been built fifteen separate cars of identical design for use on other trains as may be required. The carriages have the largest overall dimensions possible under the loading gauge regulations; they run upon two six-wheeled bogie trucks each, and the total length of each car is 68 ft. 6 in. over buffers, the length over headstocks being 65 ft. The height from rail level to top of roof is 12 ft. 1 in., and in the matter of width these carriages are also of maximum size.

Each third-class compartment seats eight persons, whilst the first-class will accommodate six, without there being even a suspicion of crowding, and this with a 23 in. corridor space in addition. The third class seats are upholstered in figured French carpet material of handsome design, and the floors and corridors are covered with linoleum of a bright pattern selected to harmonise with the colour of the seat covers and general decorations.

The woodwork is mostly in mahogany, with gold relief, and the ceiling is lined with Lincrusta Walton in white and gold. The first class car seats are upholstered with brown tapestry moquette, with silk vellum lace trimming, and the



NEW CORRIDOR TRAIN CALEDONIAN RAILWAY.

floors are covered with cashmere rugs to match.

The ceilings in the first class have white Lincrusta with gold decorations, but the electroliers, racks and blind covers are here of gilt, instead of dull bronze as in the third class.

The trains are lighted throughout on the Stone system, with an accumulator reserve sufficient for nine hours lighting of each car. Ample lavatory accommodation is provided, and the equipment includes steam heating, chain system of communication, and the most complete arrangements for ventilation possible, including special air-extractors in the roof. The guards' vans are fitted with appliances for suspending bicycles from the roof, and also safe lockers for valuables. The bogies are fitted with a new arrangement of springs, the latter being of three different types to counteract both the vertical and lateral oscillations. Between the body of each car and the the frame there is a continuous cushion of india-rubber, and patent hair felt is packed below the floors and in the sides and roofs.

Standard "West Coast" vestibules are fitted throughout, and all the wheels of the train are acted upon by Westinghouse brake apparatus. Each cars weighs 35 tons when empty, and the train of six cars will seat 264 passengers.

Similar trains are being introduced on the Glasgow to Edinburgh services.

Much-Rebuilt Locomotives.

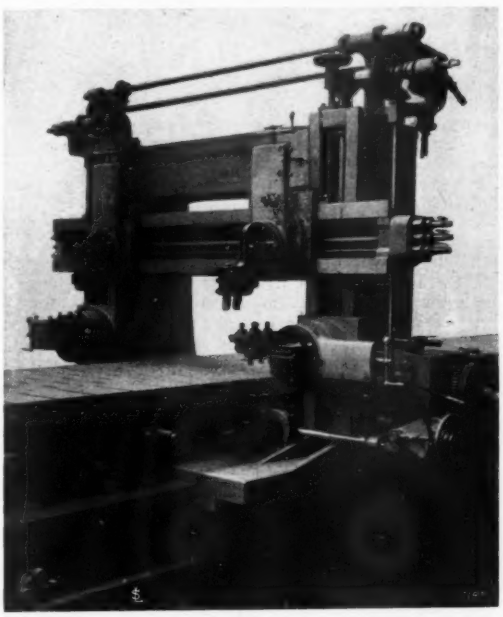
THE practice of rebuilding locomotives several times during their career is a common one in this country, and it has always been a source of astonishment to engineering visitors from abroad, that railway companies should continue to employ locomotives built in some cases as long as from thirty to forty years ago. True, very little remains of the original engine, but in many instances the design has been maintained without alteration, and good work is still being performed by locomotives which commenced their career upwards of fifty years ago. An example of this recently came under the writer's notice, when the special Scotch Express leaving Euston at 7.45 p.m. was hauled the 158 miles to Crewe in 2 hours 50 minutes without stopping, by two 7 ft. 6in. Ramsbottom "singles," one dated 1859, and the other 1862. The weight of the train was certainly not less than 275 tons without engines, and the average speed 55·7 miles per hour.

These engines, it must be remembered, have very small dimensions, the cylinders being 16 in. diameter by 24 in. stroke, and the total weight only 31 tons 7 cwts., of which 14 tons 5 cwt. rest upon the driving wheels.

Thus there would only be 28½ tons available for adhesion between the two engines, or about 9 tons less than is usual for one four-coupled locomotive of modern design.

Such proportions have, of course, become wholly unsuitable for the needs of modern heavy traffic, but the engines operated singly on trains within their hauling capacity still rank among the most efficient and economical in the country.

The American Engineering Press is somewhat given to indulging at times in satirical references to the British custom of re-building locomotives, and in a recent issue a New York journal called attention to the case of the four wheels coupled engine "Charles Dickens," which ran 2,000,000 miles in 20½ years on the London and North Western Railway. The journal in question remarked that:—"If that engine had been on an American trunk line she would probably have been scrapped years ago, with a smaller mileage, but work accomplished standing to her credit." There seems to be no reason to doubt this, but assuming the engine to have been of American manufacture, and to have been maintained in accordance with American ideas on the subject, she would probably have fallen to pieces long before attaining the record of the "Charles Dickens," and thus have rendered the scrapping operation unnecessary.



PLANING MACHINE FOR LOCOMOTIVE FRAME PLATES.

Planing Machine for Locomotive Frame Plates.

THE writer has been favoured by Messrs. Joshua Buckton & Co., Limited, of Leeds, with photographs and particulars of a large planing machine designed and constructed by them for Messrs. Robert Stephenson & Co., Limited, locomotive engineers, Darlington. The range of the machine is such that plates measuring 40 ft. long by 6 ft. wide can be planed by it, and work up to 4 ft. in height dealt with comfortably. As will be seen from the illustration, the tool carrying standards, provided with cross slides, move upon guides arranged on each side of the table and below its level, whilst the table itself and the work mounted upon it remains stationary. Two parallel screws actuate the moving head, driving it at 40 ft. per minute, and as the tool boxes are fitted with Wicksteed's patent double-cutting tool holders, the drawback of an idle return stroke is obviated, thus saving both time and power in operating the machine; all the tools of which, as will be gathered, cover a length of 40 ft. per minute, and a surface of 40 ft. multiplied by the width of the combined feeds.

The machine illustrated, although designed primarily for planing the surfaces of locomotive frame plates, may be used advantageously for planing locomotive cylinders cast in pairs, and as the table is always stationary it is possible to set a piece of work at one end whilst another piece of work is being planed at the other end.

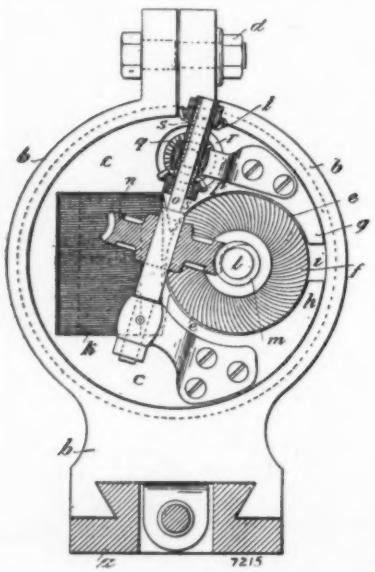
Notes from the Foreign Press.

By Dr. ALFRED GRADENWITZ.

Electro-magnetical Drive for Machine Tools.

An electro-magnetic device for driving machine tools is described in a recent issue of the *Elektrotechnische u Polytechnische Rundschau*. As will be seen from the accompanying illustration, it consists of essentially a cylindrical iron core arranged within a friction ring in which it is free to rotate. The core surrounds the armature of an electro-magnet effecting the rotation of the machine tool spindle.

On the slide, *a*, of a lathe, &c., a friction ring, *b*, is arranged, surrounding a rotary cylindrical iron core, *c*, which is free to rotate. To fix the core in the position corresponding to the work to be performed, a chuck, *d*, is used in the ordinary way. The core is bored axially at *e*, into which the armature, *f*, of an electro-motor is fitted.



ELECTRO-MAGNETIC DRIVE FOR MACHINE TOOLS.

The pole pieces, *g* and *h*, of the latter are obtained from the core by separating this at *i* by a longitudinal cut. The field magnet, *k*, the core of which is constituted by the iron core *c*, serves to generate the flux traversing the armature, *f*. A worm, *m*, engaging in the worm wheel, *n*, is keyed on to the axle, *l*, of the motor, and is fixed rigidly to a shaft, *o*, rotating in convenient bearings and carrying indirectly a conical wheel, *p*, engaging in another conical wheel, *q*, which is carried by the boring spindle. The latter, which is located in the bore *r*, traversing the whole of the core *c*, is parallel to the axis of the core and to the axle of the motor *l*. To the end issuing from the core, a drill, miller, &c., can be fixed, while the shaft can be used as well to carry a drill or miller cutter. The toothed wheel, *p*, is mounted on a socket, *s*, and is turned in a constant direction by the shaft *o*; this socket carries the counter wheel *t*, and can be shifted on the shaft *o*, so that the wheel *p* and the counter wheel *t* can be made to engage alternately in the toothed wheel, *q*, thus determining the direction of rotation of the boring spindle.

Physico-chemical Considerations on the Combustion Process in Gas Motors.

The explosion of gaseous mixtures, such as oxygen-hydrogen, is one of the most striking chemical processes, and has assumed a practical importance for chemical analysis especially in virtue of Bunsen's work on gasometrical methods, but is indebted for the general technical interest it at present offers to the adoption of gas motors.

In a paper read before the last meeting of the Association of German Engineers, Prof. W. Nernst considers the combustion process occurring in gas motors from the physico-chemical point of view, the following facts being borne out :—

The maximum amount of work that can be derived from the combustion of a given body can be calculated accurately in some cases and approximately in others. The

maximum pressure produced by the explosion of a confined gaseous mass has been investigated experimentally by various experimenters, but can be calculated theoretically from the heat of combustion and specific heat of the gases constituting the burnt mixture, provided the increase in temperature be not excessive. In the case of a very high increase in temperature, the pressure effects observed are considerably less than those calculated, owing probably in the first place to the very considerable wave motion occurring in the burning gas.

At the maximum temperature of explosion a chemical equilibrium is established, owing to the high rate of reaction. The formation of compounds which are unstable at low temperatures, such as ozone, hydrogen peroxide, nitrogen oxide, occurs especially with very high temperature. In some simple cases, the chemical equilibrium can be accounted for fully.

The propagation of combustion in an explosive gas mixture is due either to heat conduction by slow combustion or to a purely hydrodynamical process, a spontaneous combustion occurring as a consequence of the spreading of the pressure under the influence of very lively compression waves (explosion waves of Bethelot). The mechanism of propagation in both kinds of combustion can be regarded as sufficiently elucidated.

In mixtures susceptible of sufficiently rapid combustion, slow combustion will pass of itself into an explosion wave after a path of variable length has been traversed. The formation of the explosion wave may be accelerated by reflection of compression waves, striking obstacles in slow combustion, &c. Both this problem and the problem of the spontaneous combustion of gaseous mixtures under the influence of compression will require further experimental investigation for their elucidation.

The cooling of highly heated gaseous masses is due mainly, in the case of high temperatures, to radiation, and to heat conduction and convection in the case of low temperatures.

New Developments in the Construction of the Teltow Canal.

According to the *Zeitschrift für Binnenschifffahrt*, much remains to be done in the completion of the Teltow Canal, near Berlin, though the work is being continued actively. Whether the canal will be completed in the course of this autumn cannot well be ascertained. The work in the peat ground at the bottom of Teltow Lake, where the construction of lateral embankments unceasingly results in obstructions, proves especially difficult. Of the total length of the main canal and its branches (viz., 44·5 km.) about 34 km. have been completed as to the earthwork and embankments. Out of the fifty-two bridges forty-seven have been taken into operation or else completed as to the masonry and foundation work. The only sluice used in the canal, near Machnow, has been practically completed.

For the electric hauling service a large electricity station, which is nearing completion, is being erected in the neighbourhood of Zehlendorf. The hauling track has been laid in the upper section of the canal between Grünau and Britz to a length of about 10½ km., the installation of the poles having been begun. There is, accordingly, good hope of the canal being finished in the near future.

Steam Turbines for the Driving of Locomotives.

In an article recently published in *Dingler's Polytechnisches Journal*, Mr. H. A. Martens discusses the problem of a possible use of steam turbines for driving locomotives. The following requirements, according to the author, would have to be met by any substitute for present locomotive engines: equivalent or greater economy with great variations in the load: same easiness as to the graduations in speed, and especially the same ease of reversing in the case of forward and backward running; smaller dimensions, smooth running.

As to the first item mentioned, the conditions of turbine operation in connection with locomotives would be quite similar to those obtaining in the propulsion of warships where the cruising speed and forced running should be considered apart, while for both of them, an equally satisfactory utilisation of the steam is required. The Parsons turbine, in the case of constant outputs and decreasing rate of speed, the steam consumption per unit of the output increases considerably, whereas only a small alteration in the steam consumption is observed, as the output and speed are decreased simultaneously. The latter case applies to the operation of ships.

In order to improve the conditions still further, a so-called cruising turbine is inserted in front of the high speed turbines, the medium pressure turbine being fed

immediately with live steam in the case of forced running. The conditions of the load are quite similar in the case of locomotives. As regards the question whether a similar subdivision would be possible in that case, experiments will alone be able to bring about a solution. Turbines require for an economical working a satisfactory vacuum, the lowest pressure stages of the steam being those which are best utilised. As, however, condensing turbines cannot be arranged on locomotives, present day turbine systems cannot be used advantageously.

In regard to the second point, the ease of reversion is obtained in most modern turbines by using several independent forward and backward turbines, while the Elektra turbine recently constructed by the Gesellschaft für Elektrische Industrie is readily reversed by means of a simple reversing valve, admitting the steam to a double system of nozzles with two rims of running vanes for forward and backward running respectively. Which of the two solutions would be the most satisfactory in the case of locomotive operation could be ascertained only by experiment.

As regards the dimensions, referred to in the third place, some of the familiar turbine systems are characterised by moderate dimensions, while their angular speed, being rather high, involves the necessity of a wheel transmission, while other systems have moderate speeds but excessive dimensions. The advantage of a saving in weight as compared with reciprocating engines is less momentous, there being a given load on the driving axle due to the necessary friction between the rails, and which, if required, would have to be produced artificially by means of special weights.

As regards the fourth item, turbines are undoubtedly much superior to reciprocating engines from the point of view of a smooth running and small strain on the foundations.

The author infers from the above that though present-day turbine systems would seem not to be adapted for a possible operation of locomotives, this problem is likely soon to be taken up by engineers, when interesting developments may be anticipated.

ELECTRICAL NOTES.

By ANDREW STEWART, A.M.I.E.E.

Electricity on Steam Railways.*

THE author states that heavy suburban railway service is now beyond the capacity of steam locomotives, and that the next important application of electric power will be the electrification of steep grades on main lines where electric locomotives can be added to the train as pushers to maintain high speed when ascending these gradients. From these two points there will be a gradual extension of electric traction over the main line railway systems, which, however, will be slow, as the heavy expenditure, and engineering problems to be overcome, will retard development. With suburban traffic, electric motor cars and motor trains instead of electric locomotives, are desirable, for the following reasons: (1) A high rate of acceleration can be obtained. (2) A change in the weight of the train does not cause a corresponding change in the rate of acceleration. (3) The rate of acceleration can be changed to suit different conditions. (4) Shunting engines

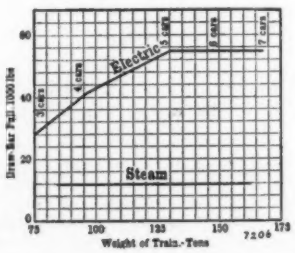


FIG. 1.

* Paper by C. F. Street to the Western Railway Club, U.S.A.

are not required. (5) Draw bar strains are distributed. With a view to illustrating the influence of motor car trains when compared with locomotives, a diagram (Fig. 1) from the Manhattan Elevated Railway showing the draw bar pull with steam locomotives and electric motor cars was given, the draw bar pull of each system being calculated as 25 per cent. of the weight of the locomotive and motor cars. This shows a draw bar pull of 12,000 lbs. in the case of the steam locomotive which is independent of the weight of the train, and for one electric motor car, 13,500 lbs., or 27,000 lbs. for a three car train, two being motor cars, and 54,000 lbs. for a five, six, or seven car train, either of which would have four motor cars. By the introduction of electric traction, one important item of expenditure is eliminated, viz., the locomotive sheds, as, of course, the electric trains, and their motor cars are handled in the carriage sheds. It appears from the expenditure at a number of locomotive sheds, that the average cost of looking after the steam locomotives, exclusive of cost of removing ashes, handling coal, cost of supplying sand, steam, heat, and water, is 6s. 2d. per locomotive per month, the cost of caring for the electric equipment is about 60 per cent. less. The practice on two lines was cited as typical, viz., to inspect each car before starting out on the road every morning. After the train has run half a mile, it is boarded by an inspector who questions the motor man regarding the performance of the train. When in constant service, motor cars make 220 miles per day, and after running 50,000 miles, are taken into the shops and overhauled. The cost per day for inspection and light repairs is 10*d.* to 1s. 0½*d.* per motor car. Assuming a six car electric train three of which are motor cars, and a similar six car steam train, the terminal charges just mentioned come out at 2s. 8*d.* per train per day for electricity, and 6s. 2*d.* per train per day for steam. The author, however, points out that this and all other comparisons must be accepted with caution, as the methods of cost-keeping on the two systems are generally different. As, however, many of his figures are from steam lines converted to electricity, there is some similarity in the method of cost-keeping. The average cost of maintaining the electric equipment of twenty-two lines comes out at ·29*d.* per car mile, or 4·33 per cent. of the total operating costs. The cost of operating the generating station varies between ·586*d.* per car mile to 1·915*d.* with an average of 1·138*d.* The cost of maintaining the generating plant is so low that it is almost unimportant; in the case of one line, with a generating plant capacity of 6,900 kilowatts (about 9,300 horse-power), the cost during 1904 was barely £140. The cost of maintaining heavy steam locomotives is given as from £700 to £750 per annum, these are results during 1904 on some American roads, but no corresponding figures for electric equipment are given, but the fact that a steam locomotive is out of service for repairs for one tenth of its life, means additional capital due to the necessity of additional locomotives to take the place of those off the road. Electrically operated cars appear to have their motor trucks out of service for 2½ to 3 per cent. of the time, while 5 to 6 per cent. of the bodies are out of service at one time for painting and revarnishing; it is usual, therefore, to have 2 or 3 per cent. extra car bodies so that when a body is in the shops for repainting, the trucks, if not in need of heavy repairs, are put under a spare body and sent out on the road. A body can be removed from the trucks and replaced by another in thirty to forty-five minutes. The cost of maintaining the electrical equipment of the roadbed is put at £29 8s. per mile of line per year. This appears to be an average of several systems, some using overhead, and others third rail systems, the former predominating. In dealing with the ratio of operating expenses for various parts of the system, to the total operating expenses, the author states that 17·335 per cent. of the operating expenses are spent on maintenance of equipment on steam lines, while the corresponding figure for electricity is 11·7 per cent. Repairs and renewals of locomotives account for 7 per cent. of the operating expenses on a steam line, and 4·33 per cent. for the electric equipment, but, as already pointed out, these should be considered as a general comparison as the cost-keeping was not identical. With regard to delays in the service due to failure of equipment, one elevated railway which increased its trains by 20 per cent., found that notwithstanding this, the delays were only one third of what they were with steam. The author cited Mr. L. B. Stillwell's remarks to the International Engineering Congress at St. Louis, to the effect that the Manhattan Elevated Railway delivers a kilowatt hour at the switchboard for 2·6 lbs. of coal, and as the efficiency from the switchboard to the car motors is 60 per cent., a kilowatt hour is delivered to the motors for 4·3 lbs. of coal or about 3·2 lbs. of coal per horse-power hour. It was pointed out during

the discussion by Professor Goss of Purdue University, that a modern simple steam locomotive would, under favourable conditions of roadbed, deliver at all times, a horse-power hour to the axle for less than 4 lbs. of coal, while a compound locomotive would do the same for less than 3 lbs. and might even reach 2·2 lbs. Mr. F. L. Lucas, manager of the Bloomington, Pontiac and Joliet Electric Railway, operated on the single-phase system, said that the energy consumption on his line appeared to be about 2 kilowatt hours per car mile, and 53 watts. per ton mile. Some engineers objected to the single-phase system by reason of its slow acceleration, but he said that the passengers commented favourably on the absence of jerking, characteristic of many direct current lines.

Electrically Operated Auxiliary Machinery in the U. S. Navy.†

THE use of electric power in the United States Navy is very extensive, and as far back as 1900 the *Kearsarge* and *Kentucky* were equipped with electric cranes, deck winches, ammunition hoists, and similar appliances; recently the six armoured cruisers of the *Pennsylvania* class, all of which will shortly be in commission, have nearly all their auxiliary machinery so operated. The undernoted table gives details of their equipment. It is usual to have two separate dynamo rooms, so that should one become disabled, the supply can be maintained from the other. The feeders are run in enamelled iron conduit, though in places, where there is no risk of mechanical damage, they are supported by porcelain hangers. The motors are all enclosed with water-tight hand holes, for access to the brushes, &c. Figs. 2 and 3 show the arrangement of the turret turning gear: each turret is manipulated by two shunt wound enclosed motors, geared together by the two mitre wheels (see Fig. 2); the worm wheel drives a vertical shaft through a friction clutch; the upper end of this shaft has a pinion which gears into the rack (see Fig. 3), thereby driving the turret. The friction clutch is either of the cone or disc type, and is intended to protect the gearing from injury due to sudden stopping of the turret, impact of firing guns, or if the turret is struck by a shot. Automatic stops are fitted to turn the controller to the off position when the turret reaches the end of the rack; positive mechanical stops are provided as an additional safeguard: as a further safeguard a dial indicator is placed in the sighting hood, so that the operator may note the position of the turret. When not in use, the turret is held in mid position by blocking wedges. A hand gear is provided (see Fig. 2) should the motors become disabled; the rotation of the turret may be anything between one per minute and one per hour. The Ward Leonard system of control is employed, and as this involves wide changes in the voltage applied to the motors in order to get the variation in speed, these turret motors are supplied either from a special generator or through a motor generator set installed in the turret. Each of the motors are large enough to operate the turret independently should one become disabled. All guns over 7 in. are elevated, and the shells rammed by electric power. The elevating mechanism consists of a shunt wound motor geared to a revolving screw which raises or lowers a nut crosshead, which operates the gun through connecting rods; in the case of the 8 in. guns, the rods are replaced by a segment of a rack into which a pinion from the motor gears. The rammer consists of a telescopic tube, operated through spur

† *American Electrician*, August, 1905.

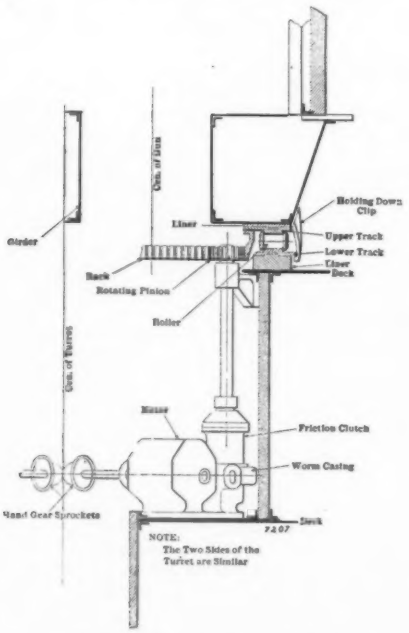


FIG. 2.—ARRANGEMENT OF TURRET-TURNING GEAR.

and chain gear by a series motor, which is fitted with a friction clutch to prevent damage when the shell is seated in the gun. Ventilation is carried out on the supply system, except wash rooms and water closets, which are on the exhaust system; shunt motors are used in all cases, and the fans are powerful enough to remove the air from quarters inside the armour once in four minutes; outside, once in twelve minutes; store rooms, once in eight minutes; wash rooms and water closets, once in six minutes; evaporator rooms, once in two and a half minutes; engine and steering-gear rooms, air spaces over boilers, and around magazines, once in two minutes; dynamo rooms, once in three-quarters of a minute. The boat cranes are operated from the weather deck, their general arrangement being shown in Figs. 4 and 5. The crane is in the form of a davit of steel plate. On the first deck, below the weather deck, is a roller bearing of sufficient size to support the crane and its load; the crane is operated by two enclosed series wound motors, one for hoisting, and one for slewing the crane. As will be seen from the plan, the hoisting motor operates through a spur and pinion and a worm gear, and the slewing motor through a similar gear, the pinion on the worm shaft being, of course, connected to a rack on the deck. An automatic mechanical brake is fitted to prevent the lowering speed exceeding twice the hoisting speed; Weston disc and cone brakes have been found very satisfactory. All the deck winches are electrically operated. The ammunition hoists for serving the larger guns consist of a car with compartments each to take one charge for the gun. This car is driven by a shunt wound motor, geared to the winding-drum by spur gear, and travels on a steel track with guide sheaves for the rope. The controller is located at the gun breech, and the gunner can watch the progress of the ammunition from the handling room to the loading platform. The chain ammunition hoists are

TABLE I.—DETAILS OF EQUIPMENT OF U.S. WARSHIPS.

—	Battleships *Kearsarge* and *Kentucky*.	Armoured cruisers *Pennsylvania* and Class.	Armoured cruisers *Tennessee* and Class (Building).
Date put in commission	1900	1905	1906
Length on load water line, ft.	368	502	502
Displacement, tons	11,600	13,785	14,500
Contract speed, knots	16	22	22
Generator capacity, kw.	50	500	600
Voltage	80	125	125
Turret Turning			
Guns in each turret	2 8in. 2 12in.	2 8in.	2 10in.
Est. rotating weight, tons	710	125	235
No. of motors to turn each turret	2	2	2
System of motor control	Ward Leonard Parallel	Ward Leonard Series	Ward Leonard Series
Motors, how connected			
Coefficient of rolling friction	·045	—	—
Ventilation.			
No. of electric fans installed	13	27	27
Nat. air delivered, cu. ft. per minute, restricted delivery	—	118,800	111,200
Est. current required for above, amperes	1080	800	725
Boat Cranes.			
No. installed on ship	4	4	4
No. motors installed per crane	1	2	2
Capacity of large cranes, lbs.	16,000	33,000	33,000
„ of small cranes, lbs.	3,000	5,600	10,000
Electric deck winches installed, number	4	7	6
„ chain ammunition hoists, number	10	34	30
„ whip „ „ „	2	4	3
„ ammunition conveyors, number	—	—	6
„ power doors and hatches, number	—	35	41
Workshop, how operated	Steam	Electric	Electric
Fresh water pumps, how operated	Hand	„	„
Drain pumps, how operated	—	„	„
Torpedo air compressor, how operated	Steam	„	„
Laundry machinery, how operated	—	„	„
Turret ammunition hoists, how operated	Electric	„	„
„ elevating gear, how operated	„	„	„
„ rammers, how operated	„	„	„

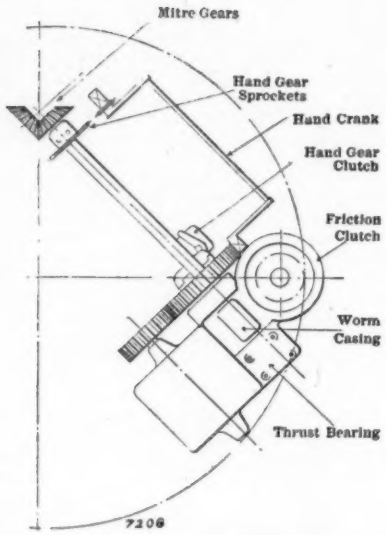


FIG. 3.—PLAN OF TURRET-TURNING GEAR.

used to supply the smaller guns, and are driven through double-reduction spur gear by enclosed shunt wound motors. At the top of the hoist is the delivery table, and a safety catch to prevent a charge from falling back down the hoist. The end of the motor shaft is fitted with a magnetic brake of the cone type to prevent the hoist slipping back should the power fail when the lift is in operation. It is also arranged so that should necessity arise, it may be operated by hand. Most of the doors are operated electrically, the details of which will be clear from Fig. 6, where a vertical door is seen. A compound motor drives a worm through spur gearing; this worm engages a rack on the door. Should the motor be out of action, the door can be operated by hand. All the emergency doors and hatches can be operated from the pilot house. In order to avoid a rush of current on the feeders, should all the doors start simultaneously, the switch is so arranged that the doors are started at intervals of three seconds.

Heat Insulating Material for Electric Furnaces.

MESSRS. R. S. HUTTON and J. R. BEARD recently submitted some notes on experiments they had made on various substances for the above purpose. These insulators, which must combine electrical as well as heat insulating qualities, are of considerable importance in electric furnace working, and have been the subject of research by several investigators. Some of the best insulators are unsuitable for very high temperatures on account of their shrinkage, though these are sometimes used for furnace linings, in conjunction with some more stable though less satisfactory insulator. The following results were obtained by surrounding a small electrically-heated tube furnace with granular powders of the under-noted substances, measurements of the power expended and the external and internal temperatures attained being made.

Material.	Conductivity.
Infusorial earth	·00013
Magnesia (light calcined)	·00016
Magnesia (fused)	·00047
Firebrick	·00028
Lime	·00029
Carborundum	·00050
Sand (white Calais)	·00060

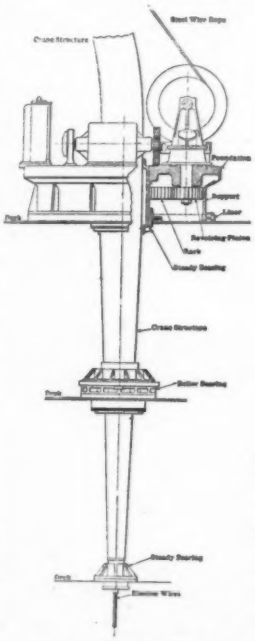
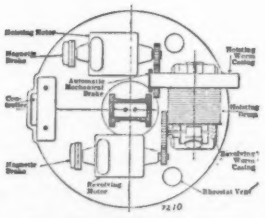


FIG. 4.—ARRANGEMENT OF BOAT CRANE.



FI4. 5.—PLAN OF BOAT CRANE.

New Locomotives on the Valtellina Railway.*

As this line is one of the earliest three-phase low frequency lines in the world, and the recent locomotives represent in many respects the most advanced practice, embodying not only the use of apparatus which then and now represents standard practice, but also such departures from recognised tramway and railway work, as a single bow trolley to collect current from the two-line wires, which are essential in three-phase working, and the water rheostat, which was so unfavourably criticised by the technical Press at the time the details of the equipment were published. These latter features have been retained in the new locomotives. At first, locomotives were employed for goods trains, and motor-cars for passenger trains, but it has now been decided to use locomotives in all cases, as many through trains are handled, and it is considered that for main-line service, locomotives involve lower inspection and maintenance charges. The earlier locomotives and motor-cars had direct connected motors with a flexible coupling between the motor and the axle. Owing to the fact that the case of an induction motor cannot be split like a direct current motor, it was necessary to press the wheels off the axles when repairs had to be undertaken; to obviate this a novel expedient was tried. The motors (Fig. 7), though they run at the same speed as the car axles, are not mounted thereon, but between the driving axles (Fig. 8), and are coupled to the latter by connecting rods, operated from a crank, seen right hand side of section (Fig. 7), to a corresponding crank on one of the driving axles. There are three driving axles coupled, as shown, so that the locomotive resembles a standard, six-coupled steam locomotive,

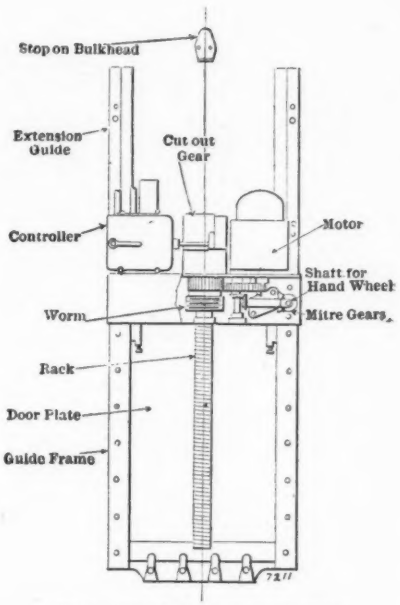


FIG. 6.—ARRANGEMENT OF POWER DOOR.

and the cranks add to the similarity. There are leading and trailing pony axles, both of which have a radial movement, and one a lateral movement also. The latter has been a feature of the Adriatic Railway steam locomotives. The motor and driver axles run at 225 revolutions per minute, and the maximum speed of the locomotive is 43½ miles per hour; there is also a half speed of 22¾ miles per hour, which is obtained with almost the same efficiency as full speed. The periodicity of the supply current is 15 cycles per second, and in this respect

* *Electrical World and Engineer*, New York, August 5th.

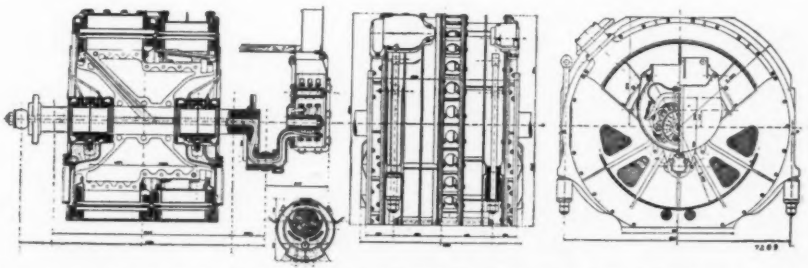


FIG. 7.—VIEWS OF MOTOR, SHOWING POSITION OF CRANKS AND COLLECTOR RINGS.

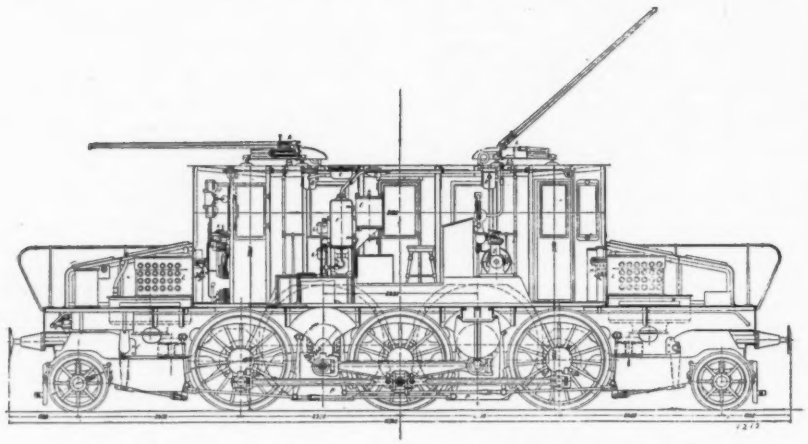


FIG. 8.—VIEW OF LOCOMOTIVE, SHOWING POSITION OF DRIVING MOTORS AND CONNECTING RODS.

resembles the new single-phase equipment on the Bavarian State Railways,* where the periodicity is $16\frac{2}{3}$ cycles. The total weight of the locomotive is 62 tons, of which 42 tons are on the drivers, 10 tons being on each of the pony axles. Only the middle axle is rigid, the other two driving axles are capable of moving about 1 in. sideways. The collector rings seen in section outside the crank (Fig. 7) project from the side of the locomotive, so that by lifting a hinged cover the rings can be examined and brushes replaced from the track almost as easily as the coupling rods may be oiled. The motors are controlled by a water rheostat, which consists of an upper part carrying the sheet-iron plates, and the lower part the water; this is forced up by compressed air. The driver controls the locomotive by means of a pneumatic master controller, which has only three levers, thus simplifying his work.

* THE ENGINEERING REVIEW, vol. 12, p. 874.

By PERCY LONGMUIR,

Carnegie Research Medallist.

Blast Furnace Practice.

Desiccated Air for the Blast Furnace.—In our March issue we gave a synopsis of the discussion arising from Mr. Gayley's first paper. Since then Mr. Gayley has published a further paper giving more detailed results, the salient features of which have been noted in these columns. However, the subject still continues to excite interest, and it may be noted that practical men are agreed in stating that any method which reduces or eliminates variables has necessarily a beneficial effect on the work and product of the furnace. On the other hand, purely theoretical men cannot explain the economies effected by abstracting moisture from the blast. However much this may be, the fact remains that adverse demonstrations on paper will not disaffirm actual furnace results as shown in the records published by Mr. Gayley.

Turning to some aspects of the discussion arising from the second paper, we note chiefly three articles in a recent issue of *Revue de Métallurgie.* M. Pourcel, in returning to the question of dried air, expresses agreement with Mr. Gayley in that its use assures a regularity of working and an economy of coke. This regularity is alone sufficient to justify the employment of desiccated air. The objection lies in the method of desiccation, and, as M. Pourcel naively adds, "it is necessary that the game pays the candle." The most obvious remedy, under the conditions existing at the Isabella Furnaces, would have been to raise the temperature of the blast, thereby effecting an immediate fuel economy. This could have been effected with less risk than that of installing a refrigerating apparatus. The real cause of the controversy, which, for the most part, lacks practical interest, lies in the published fuel economies. This discussion has obscured the least contestable point and one in which the real advantage lies, namely, regularity. With air of constant vapour content, it becomes possible to introduce into the blast furnace a volume of air of invariable weight in a given time. Hence the reaction zones of the furnace are constant and not variable, as in the case of normal blast, of which the hygrometric degree often varies from hour to hour. The most important reaction zone, that of carbon impregnation, is notably increased, as shown by the marked lowering of the temperature of the gas from the throat of the Isabella Furnace.

In the same issue of *Revue de Metallurgie*, M. Divary* brings into the discussion experience obtained by Messrs. Schneider & Co., of Creusot. Observation has established the increased fuel consumption and parallel diminution of product in the summer months as compared with the winter months. As a result of researches completed in August, 1902, the conclusion was reached that a fuel economy of from 50 to 60 kgs. of coke per ton of iron produced would be obtained by substituting air saturated at 0°C for the humid air of summer. Observations extending over a year indicated the difference in fuel consumption to be greater than that obtained by calculation. These observations are tabulated as follows:—

Month.	Average weight of water per Cu. M. of air blown during the month.	Increase in consumption of coke in comparison with the driest months.	Average production per 24 hours per furnace.
	Gr	Kg.	T.
January ...	6.3	0	90·5
February ...	6·6	10	88·7
March ...	7·6	13	87·2
April	7·8	47	81·2
May	10·0	56	78·3
June	11·7	103	75·7
July	13·0	133	70·0
August ...	12·c	90	76·6
September ...	9·3	55	90·0
October ...	8·0	28	86·0
November ...	7·6	25	86·5
December ...	7·0	35	88·5

Examining this data from another point, it is seen that an increase in consumption of coke of 133 kgs. per ton of iron corresponds to an increase in humidity of 5·12 gms. of vapour per

* Metallurgical Congress, Liège.

kg. of dry air, or 26 kgs. of coke per gm. of water. Mr. Gayley noted a diminution of 190 kgs. of coke per ton of iron for a diminution of 7 gms. of water per kg. of dry air. In other words, 27·1 kgs. of coke per gm. of water. There is more than a simple coincidence between these figures. If, on the other hand, the difference in product between the Creusot and Isabella Furnaces is examined it is found that the increase with the former is $\frac{28·6}{5·12} = 5·6$ per cent. per gm. of water. At the Isabella Furnace this increase is only $\frac{33}{9} = 3·6$ per cent. per gm. of water. This difference is explained by the fact that at Creusot the speed of the blowing engines is constant winter and summer and the blast has an average uniform temperature of 750°C. Under these conditions for equal content of humidity the Creusot production is greater than that of the Isabella Furnace.

Professor Le Chatelier discusses the matter chiefly from a theoretical standpoint, but his remarks lead one to gather that the fuel economies effected cannot be traced to a definite cause. In discussing variables, it is noted that whatever change is made in working conditions of a furnace, it is impossible to change at one time all the numerous variables which govern the quality of the product, such as amount of silicon, carbon, sulphur, temperature of metal, &c. As only one of these factors can be maintained invariable, it is asked which has been maintained constant in the experiments of Mr. Gayley. Herein lies the nucleus of the question to-day.

The Properties of Blast Furnace Coke.—A comprehensive memoir by M. Weill in a late issue of *Revue de Metallurgie* contains much of interest on the physical and chemical properties of coke. Turning to the latter it is noted that all varieties of blast furnace coke ought to contain minimum amounts of ash, water, sulphur, and phosphorus. Deleterious elements such as copper and arsenic are usually present in too small a quantity to demand attention. Generally, a type of good coke will contain from 8 to 10 per cent. of ash, but occasionally cokes are met with containing up to 18 per cent. In order to flux the ash, it is necessary to burn a certain amount of coke, this amount naturally increasing with the content of ash. Calculations given show that for each unit of ash above 10 per cent. in the coke, production costs increase by 28 fr. per day, but as ash replaces carbon in the coke, of which the real value is 29 fr. a ton, the real loss is 71 fr. per day. Water present in a coke may be due to that used for quenching or to absorption during transit or storage. Generally no maximum is specified, and as a result the amount of water varies greatly. A sample of Newcastle coke gave the low content of 1·5 per cent., but as a rule it is necessary to allow for 4, 6, or even 8 per cent of water. A coke maker is reported to have stated that his labour charges were met by water put into the coke. Sulphur exists in coke as pyrites, calcium sulphide and organic sulphur. The total quantity is very variable, ranging from 0·5 per cent. in certain Belgian and French samples up to 3·5 per cent. in Russian samples. German cokes of Ruhr vary from 0·8 to 1·5 per cent., and a similar range of variation is found in Cardiff and Newcastle samples. The content of sulphur which a blast furnace slag can retain at an even temperature of the crucible will depend on the amount of lime, magnesia, silica, alumina, and manganese. These amounts are very variable, and in consequence the saturation point of the slag for sulphur is equally so. With slags containing 48 per cent. lime, 1 per cent. magnesia, and 15 per cent. alumina, the author has never exceeded a content of 2·5 per cent. sulphur in the slag. This with coke at 1 per cent. sulphur and a fuel consumption of 1,200 kgs. per ton necessitates 480 kgs. of slag per ton of metal. Under the same conditions a coke of 1·5 per cent. sulphur would necessitate a further 240 kgs. of slag per ton to produce the same quality of metal. This in turn would involve a further 80 kgs. of coke, giving an increase in cost of production equal to 2 fr. per ton of metal. It becomes necessary then to determine in each case the maximum saturation of slag by sulphur, and up to this saturation point an increase in the sulphur of the coke causes only a minimum increase in production costs. Exceeding this point, the quantity of slag is necessarily increased if a regular grade of product is desired. Therefore the content of sulphur in the coke acts on the production and costs of the furnace in a manner which can only be determined in each particular case. Phosphorus is considered from the point of pig iron such as Bessemer grade for subsequent conversion by an acid process. Generally the content of phosphorus increases with the content of ash. Newcastle cokes contain about 0·012 per cent. phosphorus; those of the north of France from 0·022 to 0·07 per cent.; Cardiff from 0·022 to 0·05 and Ruhr coke from 0·022 to 0·035 per cent. In order to produce a pig iron of 0·06 per cent. phosphorus from hematite one of 50 per cent. iron, it is necessary to have less than 0·02 per cent. phosphorus in the ores, which are consequently costly, even when using a coke of only 0·02 per cent. phosphorus. Alkaline chlorides are sometimes found in the ash of coke, and whilst their presence has no effect on the quality of the product, they nevertheless have a very decisive effect on the furnace linings.

Steel : Its Properties and Treatment.

The Bessemer v. *The Open Hearth System.**—Mr. J. Parry discusses under this heading some of the advantages special to each process, and also some of the inherent practical difficulties. We note specially his remarks in connection with gas generators, and the proposal is as follows :—" To reject all present forms of gas

* *Iron and Coal Trade Review*, September 1, 1905.

generators with attendant grates, &c., also the draught methods or combination of ordinary draught and forced draught by steam jets or otherwise. It is proposed to rely entirely on forced draught, which can be accurately regulated, and so obviate grate difficulties, choking up grate bars, &c. In fact, the gas generator should be nothing more nor less than a blast furnace filled with fuel and blown with the usual tuyères. Of course, with no grate, the ash would be worked off as in the ordinary blast furnace slag, sufficient lime being charged with the fuel for the formation of a fusible slag. Thus we should obtain full control of the gas delivery, and, what is more important, every particle of the coal would be utilised, which is not the case at present."

Continuous Process for Manufacturing Steel.—This method, patented by Mr. H. Knoth, is described by the *Iron Trade Review* as a slag process, and may be briefly indicated as follows: An initial heat is prepared in a basic open hearth furnace in the usual manner, and before tapping the steel, the liquid slag is withdrawn into a ladle or other suitable receptacle. After tapping the steel, the furnace is repaired and recharged with liquid metal which has been blown in an acid lined converter. The molten slag from the previous heat is returned to the furnace in a liquid condition, its losses in basic properties being replaced by lime or other desired fluxing material. On account of the ready condition of the slag, the reaction between slag and metal at once commences, and the duration of the heat is materially reduced.

*On the Fragility of Soft Cemented Steels.**—A series of interesting experiments on the fragility of the soft cores of superficially cemented steels are given, and without entering into details, we note the following broad conclusions. This fragility of the core does not arise from the annealing which accompanies the cementation. Superficial cementation is accompanied by a chemical transformation of the centre of the metal, and this centre treated by the ordinary method, that is, quenched at about 800° C., becomes fragile by this treatment. By a thermal treatment and appropriate quenching, it becomes possible to suppress in part this fragility of the centre without deteriorating the hardness of the external layer. As a result, the centre of the piece has a fibrous texture save for steels which are found on the limits of two groups, and to which it is difficult to restore their original properties.

Professor Le Chatelier, in commenting on M. Lecarme's memoir, notes the interesting questions raised relative to cementation, and that their chief object should be to provoke further research. It is, however, necessary to recognise that the results given are not supported by very exact experimental proof. Thus the essential points advanced by M. Lecarme are: (1) Fragility developed in the heart of soft steels, superficially cemented, depends not so much on thermal treatment as on chemical phenomena, resulting from the nature of the cement and affecting the centre of the pieces treated.

This would be an entirely new fact if it were verified, but the results cited lead rather to the contrary. Thus in the tensile tests the heart of a cemented piece showed exactly the same properties as a bar heated under the same conditions but not cemented. As regards flexion tests it is well-known that the fracture of the cemented layer produces a crack equivalent to an extremely pointed notch, and this suffices to provoke the fragile rupture of the greater number of soft steels. One ought, however, to recognise that the experiments of M. Braune on the adverse influence of hydrogen give a probability to the conclusion of M. Lecarme, for hydrogen in the usual process of cementation may be regarded as the agent for the transference of carbon. (2.) It is possible to restore steel rendered fragile by cementation. Thus, by allowing the cemented samples to cool in air, then to reheat to above the transformation point of soft steel, *i.e.*, 900°C., and cool, finally heating to the transformation point of hard steel, *i.e.*, 780°C. and quenching.

In the following issue of *Revue de Metallurgie* M. Lecarme replies to the foregoing comment, stating that whilst full experimental results are lacking, his object was rather to give a *résumé* than a detailed account. The statement that fragility arises chiefly from a chemical modification of the central core and not from simple physical action due to annealing, is based on the fact that by annealing alone one never obtains a fragility comparable to that of cemented pieces. Thus, to again quote two tests already cited:

Test pieces taken from centre of bar.	Max. Stress Kg. per sq. m/m.	Elongation per cent.
Annealed 2 hrs. at 1000°C quenched at 800°	53·8	16·8
Cemented 2 hrs. " " "	66·2	12·5

These results are not chance ones, for the differences are accentuated by prolonging the treatment. It seems impossible to obtain a maximum stress of 66 kg. from a soft steel by purely physical treatment.

General Metallurgy.

"Alloys of Copper and Aluminium."—M. Guillet opens his study* with a review of work previously done in the field of copper-aluminium alloys, drawing special attention to and reproducing the fusibility curves obtained by Le Chatelier. The theoretical part of the paper is comparatively long, and possesses little of direct interest. Turning to the practical side we note much of interest and value. Industrially it is necessary to recognise two distinct sets of copper aluminium alloys, viz., those rich in

* M. J. Lecarme, *Revue de Metallurgie*, Vol. ii., No. 7.

* *Revue de Metallurgie*, Vol. ii., No. 8.

copper, containing up to 10 per cent. aluminium, and on the other hand those rich in aluminium containing from three to six per cent. copper. The first set are known as aluminium bronzes, whilst the second are sold under the name of aluminium, and are utilised in the construction of certain parts for automobiles. In preparing these alloys freedom from oxidation is necessary, and castings are best poured by means of a plug head. The high contraction must also be allowed for. Up to a content of 10 per cent. aluminium the alloys may be rolled, but they can only be drawn with difficulty when the aluminium exceeds 7 per cent. In colour the alloys are golden up to a content of 14 per cent. aluminium, but as this amount is exceeded they become white, grey and silver white. Up to 10 per cent. aluminium the alloys are malleable, but at 11 per cent. they become fragile. The difficulty of preparation also increases as the alloys increase in aluminium. Malleability only commences to return when the content of aluminium exceeds 66 per cent. Tensile results obtained from the alloys in various conditions are given in the opposite table.

Some interesting quenching results are included, and the general effect appears to be that of increasing breaking load and elongation, an effect more pronounced in the case of cast than rolled material. Complex aluminium bronzes represent alloys to which an addition such as silicon has been made with a view to improving the quality. A series of these complex bronzes are given in the following table :—

Alloy.		Elastic Limit. Kg. per sq. m/m.	Max. Stress. Kg. per sq. m/m.	Elongation per cent.
Cast	Al. commercially pure ...	3·0	9·4	7
	Al + 1 per cent. Cu ...	3·3	10·3	5
	Al + 2 per cent. Cu ...	4·0	10·9	4·5
	Al + 3 per cent. Cu ...	4·9	12·0	5
	Al + 4 per cent. Cu ..	5·2	12·9	6
	Al + 5 per cent. Cu ...	5·0	13·2	3
	Al + 6 per cent. Cu ...	5·2	13·6	2
Cast	Cu + 3 per cent. Al ...	7·9	20·9	36
	Cu + 5 per cent. Al ...	8·4	23·9	53
	Cu + 7 per cent. Al ...	9·1	25·4	66
	Cu + 10 per cent. Al ...	16·9	30·5	6
Al commercially pure annealed		4·83	11·0	23
Al commercially pure cold worked		5·1	11·2	11
Alloy at 2·5 per cent. Cu		6·3	19·8	11·5
Alloy at 3·6 per cent. Cu		6·6	21·4	20
Alloy at 91·95 per cent. Cu ...		42·9	46·2	43
Alloy at 92·23 per cent. Cu ...		34·7	43·2	54
Aluminium pure annealed ...		—	12	31
Aluminium Bronze cold worked		—	16	
Alloy at 3 per cent. Cu annealed		—	19	9·5
Alloy at 3 per cent. Cu cold worked		—	22	4·5
Alloy at 6 per cent. Cu annealed		—	20	11
Alloy at 6 per cent. Cu cold worked		—	25	4
Aluminium Bronze at 7 per cent. Al annealed		—	40	4·5
Aluminium Bronze cold worked		—	80	3

Composition.					Tensile Properties.		
Cu.	Al.	Fe.	Si.	S.	Elastic Limit. Kg. per sq. m/m.	Max. Stress. Kg. per sq. m/m.	Elongation per cent.
			On Cast Bars.				
99·74	—	—	—	—	9·1	21·6	26·7
93·35	4·62	0·89	0·98	0·04	9·7	37·4	46·6
91·17	5·92	0·78	2·12	0·04	15·7	49·6	28·1
90·43	7·50	0·54	1·54	0·05	14·2	48·6	31·3
89·67	7·08	0·72	2·72	0·12	22·2	53·1	7·4
86·07	10·05	0·98	2·48	0·14	?	62·9	0·15
			On Rolled Bars.				
90·99	7·96	—	1·36	—	21·6	49·9	18·4
90·38	8·29	—	1·41	0·04	25·1	53·9	15·3
89·77	7·43	0·54	2·53	—	25·2	57·9	16·5
91·66	6·69	—	1·83	0·04	23·3	52·5	33·5
90·38	7·62	0·73	1·44	—	21·1	52·0	25·3
88·83	7·19	2·27	1·32	0·05	19·8	52·2	35·4
93·59	4·99	0·91	0·91	—	17·3	43·7	41·6
89·99	7·98	0·89	1·23	—	21·8	50·9	12·5
86·71	9·80	0·73	2·38	—	31·3	69·6	0·4
89·98	7·37	1·02	1·95	—	20·6	55·4	18·3
88·16	11·01	0·34	0·80	—	31·1	51·1	0·2
90·50	8·81	0·56	0·01	—	22·3	50·7	20·7

In this section is presented every month a list of the principal contents of the leading organs of the technical press and of the proceedings of learned societies throughout Great Britain, the Continent, and America. An alphabetically-arranged list of the publications regularly reviewed, together with the place of publication and price, was given on pages 195—196 of the August issue.

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Streets and Pavements.

ENGINEERING ECONOMICS. MISCELLANEOUS.

The Latest 12-inch Breech-loading Wire-wound Guns. *Engineer*, 8*th September*, 1905.

The Principles that should Govern the Allotment to, and the Employment in, Coast Fortresses of Light Quick-firing Guns, and the Methods of Fire Control and Direction best suited to obtain Effective Fire. *Journal Royal Artillery, August*, 1905.

Ore Unloading Machines for use at Receiving Docks. *Engineering News*, 3*rd August*, 1905.

Accidental Breakage of Winding Ropes in Mines. *Engineer*, 1*st September*, 1905.

Federal Testing Laboratory. *La Machine*, 10*th* and 25*th August*, 1905.

BOOK REVIEW.

The Crystallisation of Iron and Steel, an Introduction to the Study of Metallography. By J. W. MELLOR, D.Sc. (London: Longmans, Green & Co.). Price, 5*s.* net.

This work embodies a series of six lectures delivered to engineering students of the Staffordshire County Technical Classes, and is intended to summarise the more important researches made on the constitution of iron and steel. To this end the author has read widely, as illustrated by nearly two hundred references in the text. The researches drawn on are chiefly those of Arnold, Stead, Osmond and Ewing, to whom the author is also largely indebted for his illustrations. As a summary of past work the book is excellent, and very clearly indicates the present position of metallography, but as a student's guide its purpose is not so well filled. Thus in the section devoted to the constituents of iron and steel the author describes martensite, and illustrates it by means of a photo-micrograph by Heyn, then proceeds to state (p. 41) :—

"It is frequently very difficult, if not impossible, to detect the crystalline structure of martensite in properly hardened steel."

The student will not unnaturally view a properly hardened sample as the best means of studying the constitution of such steels. Turning to another phase of hardened steels :—

"Austenite is said to be so soft that it can be scratched with a knitting needle. Some deny the existence of austenite altogether" (p. 41).

Here we fail to obtain any direct guidance, and such is also the case in regard to troostite and sorbite.

"I daresay that it would be quite possible to get an infinite number of gradations between martensite proper and pearlite. All we can say is that two predominating patterns are called troostite and sorbite" (p. 43).

In treatment, the work lacks direction, and we venture to think that had the author relied less on published matter and more on his own experimental work, not only would its style have been more direct, but the reliability of the work would have been greater.

The Olympia Electrical Exhibition.

SPECIAL interest attaches to the electrical exhibition which was opened on Monday, September 25th, by the Lord Mayor of London, by reason of the fact that it is perhaps on a more important and comprehensive scale than any held in the metropolis for some years past, and, further, that it has been undertaken under the patronage of the Institution of Electrical Engineers and the auspices of the National Electrical Manufacturers' Association.

Judging from the material exhibited, its primary object has been to appeal, not so much to those interested in the heavier branches of electrical engineering, as to the consumer and the contractor. Nevertheless, members of the electrical profession will find plenty of material to interest them in spite of the absence of heavy plant, and there can be no doubt that the anticipations of the organisers have been amply fulfilled in their endeavour to secure a representative electrical show. Electric lighting is perhaps as well or better represented than any other branch, and many examples of lamps of all types, from the flame arc lamp down to the newest "Tantalum" and "Thorium" lamps, are found on view and in use, and also in process of manufacture in the exhibition. Auxiliary apparatus connected with the distribution and use of electricity is also well represented by many exhibits; in particular may be mentioned accumulators, resistances, conductors, meters, fuseboards, and switches. Fittings, of which there are numerous artistic and interesting displays, form another prominent feature, while amongst the smaller but distinctly valuable uses of electricity represented, reference must be made to the electrical cooking and heating apparatus, which well deserves attention. Nor has electrochemistry been overlooked, daily demonstrations being given with a model steel refining furnace, and with an electric furnace of the "Moissan" type, such as the preparation of rare and highly refractory metals, fusion and volatilisation of highly refractory substances, &c.

The telephonic and telegraphic branches are well cared for, being represented by many prominent firms, including the Marconi Co., as well as by the Postal Telegraph Department, who show an interesting loan collection. The telegraphone and telautograph, representing the most recent developments in this section, are subjects of interesting demonstrations.

Dynamos and motors there are in abundance, amongst the latter being some new developments to be noted at the stands of Electromotors, Limited, and the Morris-Hawkins Electrical Co., Limited.

Space prevents us from dealing in full with the various exhibits, but appended is a brief description of some of the more important and novel amongst them.

THE MORRIS-HAWKINS ELECTRICAL CO., LTD., 17, CHARING CROSS ROAD, LONDON.

THIS exhibit is one of exceptional interest. Coupled together on a combination bed-plate are two 35 h.-p. machines running on "Hopkinson" test with the idea of demonstrating the heavy overloads that can be obtained. The motors have special features, inasmuch as they are fitted with the firm's new commutating magnets. The application of the commutating magnets is, of course, not a new one, but the design of the particular magnet adopted by the Morris-Hawkins Electrical Co., Ltd., would appear to have several good points.

The accompanying illustration gives a clear idea of the general design. It will be seen that the pole core of the commutating magnet is circular in section, thereby economising in copper and in the consumption of energy. In order to take advantage of the circular section, the magnets are mounted outside of the common symmetry plane of the main magnets.

The design being of simple construction, it is cheap to manufacture and especially adapted for the line of standard motors manufactured by the firm.

There is no doubt that a good commutating magnet fulfills a very necessary want, especially on motors built for four hundred to five hundred volts circuits, as in such machines the reactance voltage cannot be kept sufficiently low to ensure sparkless collection on the geometrical neutral point.

The accompanying photograph shows the design of a Morris-Hawkins 4-pole motor fitted with their patent commutating magnets. There are, of course, four such magnets, each magnet consisting of a pole shoe, magnet core, and an exciting coil, the exciting coil being connected up in series with the armature winding. The magnet core is fixed to the main yoke by studs. The magnet core is circular in section, and is mounted outside of the symmetry plane of the main magnets; with the object of reducing the self induction

of the armature coils under commutation, the pole shoes of the main magnets and commutating magnets are connected together by means of copper strips. The chief advantage of this design of commutating magnet is its extreme simplicity and its small cost of manufacture, while the current absorbed in its excitation is very small. A test on a 35 b.h.-p. motor supplied to Messrs. Hulse & Co., of Salford, for driving a planing machine, gave the results plotted on the accompanying diagram.

From this it will be seen that the load varied between 10 b.h.-p. and 65 b.h.-p., and this excessive overload occurred about four times per minute.

The motor is wound for 440 volts and runs at 760 revolutions per minute, and at the time of the test there was a 10-ton object on the table, although the motor at different times has dealt with an object weighing 17-tons on the table. The following are the principal dimensions of the planing machine in question :—

Length of table, 28 ft.; weight of table, 14-tons; width of table, 7 ft.; travelling speed cutting, 20 ft.; travelling speed backing, 45 ft.; maximum weight of job, 20-tons.

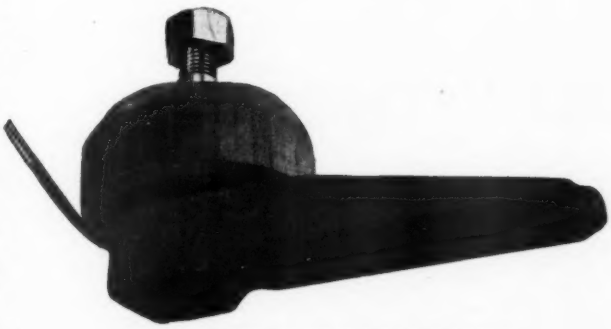
The motor dealt with this overload, which attains about 80 per cent. above the normal rating and with a complete absence of sparking, with the brushes fixed in the geometrical neutral position.

The application of the commutating magnet, as described, refers to a motor running at constant speed and in one direction of rotation, but they have, of course, as great a value for reversible motors and for motors where speed variation is required.

With regard to variable speed motors, the Morris-Hawkins Co. are fitting their patent magnets on all 500 volt machines. They have, in addition, developed a new method of speed regulation which is independent of the weakening of the field by shunt control. The speed variation of this patent motor is effected by altering the reluctance of the magnetic circuits of the motor. This is accomplished entirely by mechanical means in a simple and efficient manner, ensuring a thoroughly sound construction. The variable speed motor does not require any separate electrical apparatus for its operation beyond the ordinary starting switch.

The variable speed motor exhibited at the stand gives 7 h.-p. and 350 to 950 revolutions per minute, and can be seen in operation.

MORRIS-HAWKINS MOTOR: MACHINE WITH ARMATURE REMOVED, SHOWING ARRANGEMENT OF POLES.



MORRIS-HAWKINS MOTOR: ONE OF THE SERIES POLES.

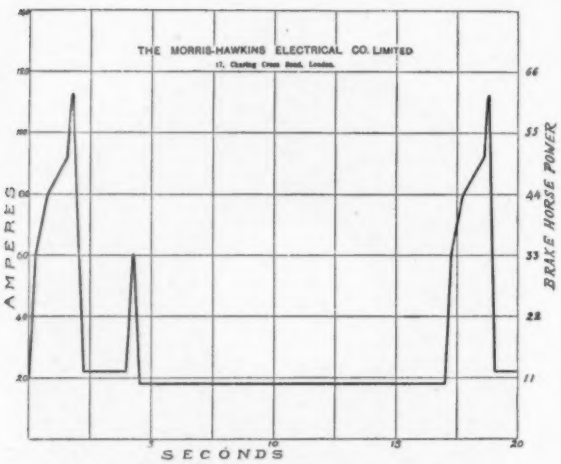


DIAGRAM SHOWING RESULTS OF TEST ON A 35 B.H.-P. MORRIS-HAWKINS MOTOR.

FERRANTI, LTD., HOLLINWOOD.

The most noticeable about this stand is, perhaps, the entire absence of the enamelled slate cellular form of switchboards so long associated with the name of this company. Various cellular constructions are, indeed, shown, but these differ very materially from the old type as manufactured by the company, having been brought thoroughly up-to-date.

The exhibit which most nearly represents the old type of Ferranti cellular gear is a sample generator panel with bus-bar extension, which is a duplicate of one of some forty-eight more or less similar panels recently supplied to the order of the Sydney Corporation, but even in this sample it will be noticed that the old oil porcelain fuses have disappeared and been replaced by an automatic circuit breaker, which is entirely separated from the switchboard attendant by a substantial enamelled slate front. The switch is of the well-known tank type. Each phase is in a separate tank, the breaks being entirely under oil.

Another example of a cellular board is represented, and consists of a typical generator, feeder and summation panel. All bus-bars, current and potential transformers, isolating switches, and circuit breakers are enclosed in separate concrete cells, closed by substantial iron doors.

The switches are of the remote control type arranged for operation from a bench control board erected overhead on an upper gallery. A small portion of a gallery has been installed along one end of the exhibit.

A less expensive type of high tension gear for controlling smaller powers and where a gallery is not available, is illustrated in a section of a semi-ironclad switchboard. This consists of a generator, summation and two-feeder panels. Each panel is bounded on the two sides by substantial iron sheet, on the front by the marble panel supporting the instruments, &c., and is closed at the back by suitable iron doors. Isolating switches are provided, so that when these are opened a man can safely enter any panel for the purpose of repairs, he being virtually within an earthed iron box.

The continuous current boards represent sample panels for traction, lighting and power work; while isolated high and low tension motor panels may also be inspected.

There is, furthermore, a large display of the various accessories requisite in the construction of switchboards, slow and quick-brake switches, circuit breakers, rheostats, starters, instruments, meters, relays, &c. Particularly to be noted is a new type of direct-current circuit breaker. This is on the carbon break principle, and possesses several interesting features. The carbon on the movable arm is arranged to swivel so as to give the best possible contact with its partner. The latter is attached to a sliding sleeve pressed outwards by a strong spring. This spring serves the double purpose of providing a quick break, acting as it does at the maximum radius on a movable arm, and it also insures that the carbon supported by the fixed portion of the circuit-breaker follows the other sufficiently far during the opening motion to insure that the final break occurs between the carbons and not between the main contacts. The breaker is closed by a very simple toggle joint arrangement, and no solenoid is required for the overload tripping mechanism. These circuit-breakers are made for both overload and reverse current.

A new type of feeder charging gear suitable for three-phase circuits up to 10,000 volts is also shown. It consists of six cast iron circular tanks supported on heavy porcelain insulators. Inside each tank, and concentric with the same, a porcelain pipe is fixed and copper rods connected together are gradually lowered by suitable mechanism into cast iron tanks. The latter are filled with water, and contain in the bottom a small cast iron pan of mercury. The cast tanks themselves form the terminals of the different phases, so that no flexible connections are required.

Solenoid operated remote control switches connected with time limit overload and reverse power relays are shown in operation.

VICKERS, SONS AND MAXIM, LTD., SHEFFIELD.

Users of planing machines and other reciprocating tools will find an object of attraction at Messrs. Vickers, Sons and Maxim's stand, whereon is shown in action a planing machine 5 ft. by 5 ft. by 12 ft. direct driven by a Vicker's variable speed motor and reversed automatically by the firm's patent switchgear without the use of belts. The introduction of this apparatus marks a distinct advance on the present methods of driving reciprocating machines and, briefly described, the equipment consists of a variable speed shunt wound motor and special switches worked from the driving gear. The functions of the switches are to start the motor after it has come to rest at the end of the stroke; to insert or withdraw resistance in series with the field coils, thus altering the speed after reversal; to reverse the armature connections and thus reverse the direction of rotation; to retard the armature at the end of the stroke by strengthening the field prior to reversal. The speed variation of the motor, which ranges from 300 to 900 revolutions per minute, is produced entirely by varying the shunt current and the efficiency of the motor is given as 87 per cent. under all circumstances. A feature of the apparatus, which enhances the value of the planing machine, is the ability to vary the cutting speed instantly by simply turning the handle of the controlling switch to the proper position. Another advantage is that a positive and quick reversal is obtained, obviating the loss of time which often occurs when a belt has become slack and worn. The ratio of cutting speed to quick return speed is about 4 to 1·on this particular motor. A 5-ton electric hoisting winch and a range of crane motors complete an exhibit of more than ordinary interest.

PLANING MACHINE DRIVEN BY THE VICKER'S VARIABLE SPEED MOTOR.

SUNBEAM LAMP CO., LTD., GATESHEAD.

This company show a working exhibit of their well-known "Sunbeam" lamps, including large and small candle flames in a variety of forms, "Outshine" lamps, the original "Sunbeam" heating lamp, a striking novelty in the shape of a reducing lamp for increasing and decreasing light, reflector lamps, high candle-power lamps including one of the largest ever made, namely, 3,000 c.p. A showcase displays a variety of lamps in various stages of manufacture, and an interesting exhibit is completed by a range of motor starters, iron-clad switches, radiators, fans and lighting accessories.

JAMES KEITH AND BLACKMAN, CO., LTD., 27, FARRINGDON AVENUE, E.C.

Included in this exhibit are one or two specialities recently introduced by the company, in particular an 8 in. electrically driven high-pressure blower, for use with furnaces, cupolas, forges, &c. Both motor and blower are arranged in one casing, forming a very nea design. We understand that these blowers are to be had in six sizes, with outlets ranging from 2 ins. up to 12 ins. in diameter, and capable of giving with efficiency and suitable volume water gauge, wind of from 5 ins. to 20 ins. pressure.

Another feature is a forge hearth and combined motor and blower, arranged for fitting direct to the tuyères of each forge, thus rendering each fire independent. The power required varies from 100 watts for light work to 300 watts for heavy work, and as no power is used when the fire is not being blown, the average power will be from 50 to 33 per cent. of the above figures. One casting forms the casing of the

blower and the field of the motor. The air propeller is of aluminium, and the weight of the revolving part is very small. An extension of the blower fits inside the tuyère and carries a valve which prevents the gases from the fire coming back into the blower, and which is opened and closed automatically by the air.

The remaining special feature of the stand is a 9 in. electric fan with motor combined, specially constructed with an extended spindle and tube for refrigerating plants. Other exhibits included a set of standard fans combined with series wound motors for direct current; two fans combined with A.C. induction type motors; switch board showing various types of "Keith-Blackman" rheostats for starting and regulating fan motors.

MESSRS. GEO. RICHARDS' PATENT MOULD DRYER.

GEO. RICHARDS & CO., BROADHEATH, MANCHESTER.

Machine tools, including a 3 ft. 6 in. belt-driven radial drilling machine; a small sensitive drilling machine; and a 3 ft. patent boring and turning machine, constitute the conspicuous features of this stand. Prominently displayed, however, is a novelty recently introduced by Messrs. Richards in the shape of a patent mould dryer depicted in the accompanying illustration. The apparatus consists of an outer casing containing an inner cylindrical fireplace which is lined with gannister. A flat hearth is arranged a short distance from the bottom to support the coke fire through which air is driven by an injector. The air, which is supplied at about 20 lb. pressure, flows into the casing, part of it going through the top of the inner fireplace, and the other part passing through a perforated adjustable ring and down the annular space between the fireplace and the outer casing. The hot and cold gases are mixed in the chamber below, the temperature being regulated by means of the cold air to prevent burning of the moulds. The apparatus weighs only 3 cwt., and can thus be moved easily by two men.

A notable feature is that, the air passing downward through the fire, the carbon and smoke is consumed, thus preventing the deposition of cinder and soot on the moulds. A variety of "cling rim" pulleys completed the exhibit. These derive their name from the fact that after being turned and bored in the usual way the rims are given a coarse grained surface, the effect of which is to increase the clinging power between the belt and rim, an advantage sufficiently obvious.

E. GREEN & SON, LTD., MANCHESTER.

This stand looms conspicuously in the exhibition, and is certainly one of the most effective arrangements ever adopted by this firm.

The exhibit consists of Green's Patent Fuel Economiser containing 48 tubes, giving approximately 500 sq. ft. heating surface. The scraper gear is in motion, driven by a 1 h.-p. direct-geared motor. Coupled to the economiser is one of the new patent direct-acting "Wakefield" steam pumps, showing the method of forcing the feed water through the apparatus.

On the same foundation is erected a Green's Patent Air Heater, containing 32 tubes, providing a 400 sq. ft. heating surface. This apparatus also utilises the waste heat in the flue gases for supplying hot air to the drying rooms, where the rapid drying of materials in process of manufacture is a necessity. It can also be worked separately, or as shown; namely, in conjunction with the feed water economiser. The scrapers on the vertical tubes are in motion, being driven by the motor attached to the gearing frame of the economiser. These scrapers are of the crab-jaw type. Coupled to the heater is an 18 in. motor-driven "Clinker" fan, which forces the cold air through the apparatus, the hot air emerging from the connection at the top of the heater.

There is also on the stand a complete model of Green's Economiser coupled to a Lancashire steam boiler plant. This model is particularly interesting, and shows exactly how the economiser is placed in the main flue to intercept the

gases passing from the boiler to the chimney stack. The model contains 72 heating tubes arranged on the modern principle in two groups and with space at the back to allow of easy access to any part of the apparatus. The damper arrangement and bye-pass flues are also shown. The scraper gear is in motion, being driven by a small electric motor. Also to be noticed is a 5 in. high speed horizontal steam engine with fly wheel complete. This type of small engine has, we understand, been largely adopted for driving mechanical stokers, conveyors, fans, or small workshops where little power is required.

At one corner of the stand there is a 4 in. double ram pump of the fly-wheel type, which is extensively used for feeding economisers and steam boilers. It can also be arranged as a fire pump.

To indicate the quality of the metal the economiser constructed from a piece of vertical tube that has been burst under hydraulic pressure of close upon 4,000 lbs. to the square inch, is on view, together with laboratory certificate of test.

Specimen castings of tubes and top and bottom boxes are also exhibited, and various diplomas, indicative of the high awards that have been awarded to Green's Economiser at previous exhibitions

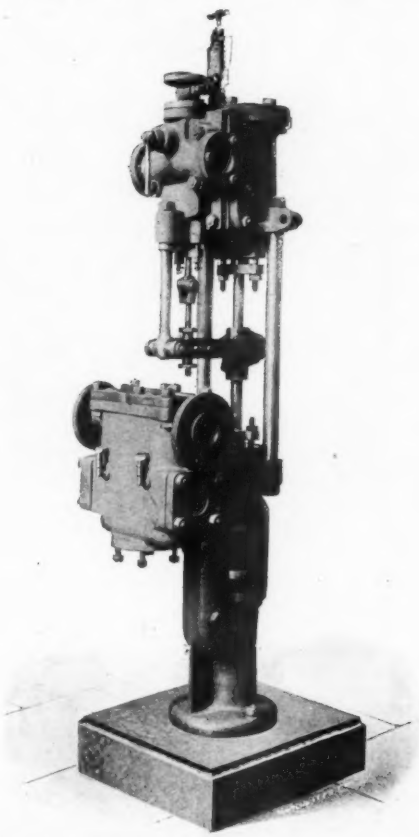
MESSRS. FRANK PEARN & CO., LTD. MANCHESTER.

This firm exhibit a variety of their specialties, including a range of single-acting "Manchester" donkey, or wall pumps with rams, rising in sizes from 1 in. to 3 in. diameter; double ram "Cameron" type pumps, also double-acting ram pumps constructed with the firm's patent method of packing the ram, which is precisely the same as employed in a single acting ram pump, viz.: that there is only one stuffing box requiring attention.

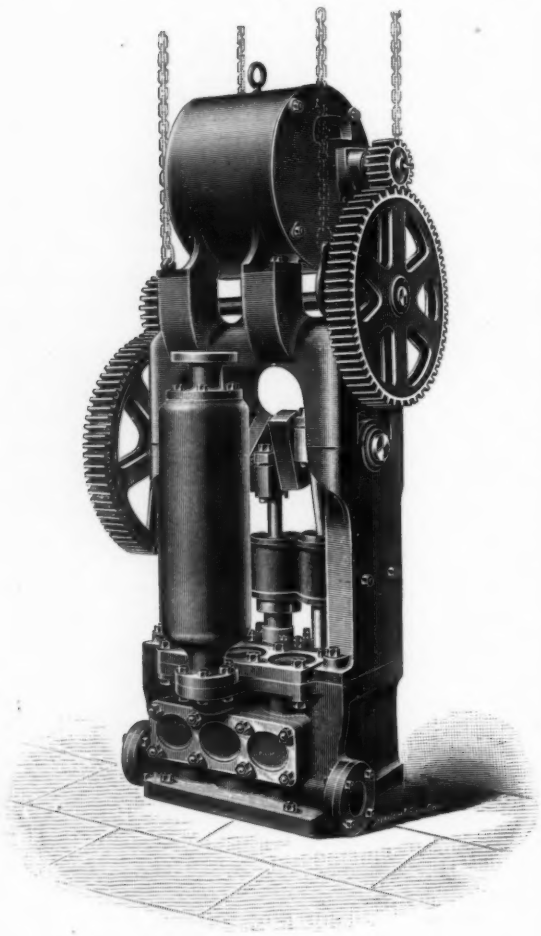
A vertical duplex ram pump, also constructed with their patent method of packing the rams, is also shown.

There is also an excellent exhibit of this company's new series of vertical power pumps with one, two and three rams. The single ram pump, with ram 2 in. diameter by 3 in. stroke, is shown in motion, being driven by a ½ b.h.-p. motor. Quantities of these pumps, we are informed, have been erected for the supply of water to small estates, farms, &c. There is also a treble ram pump in motion, having rams 3 in. diameter, stroke 5 in., driven by a 6 b.h.-p. motor, and suitable for a working pressure of 160 lbs. per sq. in. We understand this pump is extensively used for boiler feeding and work in connection with collieries, gold mines, &c. Another exhibit of this series of pumps is shown with the motor placed above the pump for use in positions where the floor space is restricted. This is an admirable type of pump for sinking purposes, as it slings well on account of the even distribution of weight. We notice this pump is made for the Electric Construction Co., Ltd., Wolverhampton, and is part of a contract for the London County Council. The notable features of this series of pumps are accessibility, compactness and durability, they having been designed to occupy the least possible space consistent with ease of access to the glands, valve doors, bearings, &c. All the wearing parts are of ample surface, and the pumps are substantially built for long and hard service.

Perhaps the most interesting exhibit among Messrs. Pearn's fine collection is a new departure in direct-acting steam pumps. The chief claim to notice is the admirable arrangement of admitting steam to the cylinder, which is done in a similar manner to a rotative pump, namely, that the main steam port is only



MESSRS. PEARN'S NEW PATENT DIRECT DOUBLE-ACTING PUMP.



MESSRS. F. PEARN & CO.: SINKING TYPE PUMP.

slightly opened at the commencement of the stroke, such opening gradually increasing with the travel of the piston. By this means the steam is not shot on to the piston in the same manner as in most direct-acting pump steam cylinders. It reverses quickly and closes the water valves without concussion, which is so destructive to most direct-acting types of pump. We hope in a future issue to publish full details and drawings of this neat and effective piece of apparatus. A well-designed and compact vertical air compressor driven by a 3 b.h.-p. motor completes the exhibits of this company.

THE LANCASHIRE DYNAMO AND MOTOR CO., LTD., MANCHESTER.

This company are showing an automatic reversible booster—Turnbull and McLeod patent—similar to the one shown at the Tramways Exhibition. The motor for this is wound to turn off 500/550 volt circuit, and the booster is capable of developing 200 amps. 0/120 volts continuously, 300 amps. for one hour, and 400 amps. for five minutes at 0/60 volts, the set running at 800 revolutions per minute. The particular features of this machine may be summarised as follows: — The laminated fields give very quick reversal. Further, the booster is easily paralleled, and it is possible to arrange by suitable adjustment of the field resistances, either for constant load on the generator, or for a load on the generator varying within certain limits, anything above these limits being taken by the battery. The alteration of the dynamo shunt regulator does not necessitate any alteration in the booster field regulator, as it is self-regulating. There is no hunting, and charge and discharge currents can be adjusted to suit the particular conditions of the generating station.

Also prominently displayed is a set of induction motors of 20, 14 and 10 h.-p. respectively, all wound for 60 period circuit at 1,150 revolutions, these being the company's standard short circuited rotor type. Special attention has been paid to the mechanical construction of these machines, and to be specially noted is the centering device in the end-plate, by means of which, should the bearings wear, the air pump may be adjusted from the outside of the motor.

Continuous current machines of 15, 5 and 4 h.-p. are on view, the latter being coupled to a "Davidson" blower.

On the stand is also a balancer set, consisting of two standard machines coupled back to back, this set having two bearings only. The construction is specially strong, as the armatures are built upon a cast iron sleeve, which extends from the bearing at the one end and is formed into a coupling of large diameter at the other end. This half coupling is bolted to a corresponding one on the other machine, making a very rigid job. Balancing has received particular attention, and the makers claim for them

that they are more efficient and less expensive than the three-bearing machines, as the third bearing is often a source of trouble.

The motor starting panels exhibited on this stand are by Messrs. Brook, Hirst & Co., and the automatic booster switch panel by Mr. Bertram Thomas, of Manchester.

THE DIESEL ENGINE CO., LTD., 17, QUEEN VICTORIA ST., E.C.

Among the novelties is to be noted a 20 b.h.-p. crude oil engine, which is shown by this company direct-coupled to a dynamo. It may seem strange to refer to an engine as a novelty when, as we are informed, about 2,000 have been sold, aggregating nearly 100,000 h.-p. But it happens that this is the first occasion on which such a plant has been exhibited in this country, and in this sense it is a novelty and a very interesting one

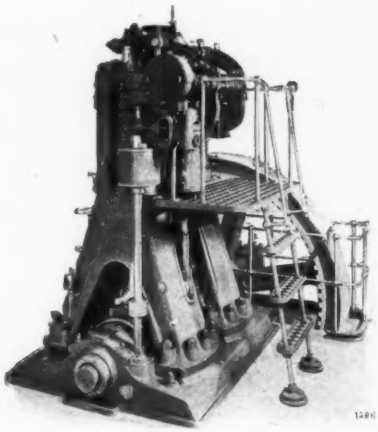
The fuel is crude oil, such as Texas, Pennsylvanian or Roumanian, quite uninflammable under ordinary conditions; lighted matches for instance may be thrown into it with impunity. The engine has no vapouriser, naked flames or igniter of any sort, and combustion is so perfect that the exhaust is practically without smoke or smell. For private house lighting, a small plant such as the one shown should at once compel attention. The plant is self-starting, and current is available in from one to two minutes any time. The cost is wonderfully low, being about $\frac{1}{10}d.$ per b.h.-p. hour, with oil at 40*s.* a ton (2*d.* per gallon). Ten 16 c.-p. or twenty 8 c.-p. lamps can be fully incandesced for $\frac{1}{10}d.$ per hour, or for 10 hours for 1*d.*

The engines are made in sizes from 8 to 500 b.h.-p., and many of the larger sizes are in use for lighting and traction purposes in central stations all over the world.

THE EDISON AND SWAN UNITED ELECTRIC LIGHT COMPANY, LTD., QUEEN ST., E.C.

This company are represented at a stand 50 ft. long by 20 ft. wide, holding one of the most prominent positions in the centre of the hall. It is divided into three sections, one for lamp exhibits, another for engineering specialties, and a central reception room, in which are shown the various articles mentioned below.

The company are making a strong feature of the manufacture of incandescent lamps. A space 20 ft. by 15 ft. has been devoted to this purpose, and employees from the works at Ponder's End are engaged in demonstrating the many various processes in the manufacture of the same. The company is also showing all their specialities in lamps, including the well-known Radiolite lamp. Another interesting exhibit is the historical section, in which the progress of lamp making is traced from the earliest examples.



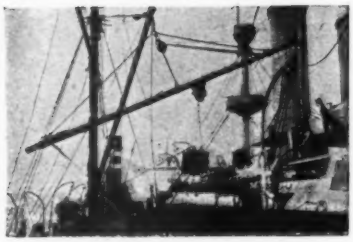
20 B.H.-P. DIESEL OIL ENGINE.

In the engineering section, also 20 ft. by 15 ft., are exhibited the various manufactures of the company, such as traction, ship, factory, and colliery fittings, hand lamps, ceiling roses, switches, &c. A prominent exhibit is that of measuring instruments, notably the latest improved form of moving coil type. Among other things too numerous to mention, there are exhibited bells, indicators, pushes, batteries, while the latest pattern of fuseboards, distribution boards and switchboards also hold an important position. Altogether the exhibit is a very complete one, illustrating the application of electricity to house and general lighting, heating and ventilating, in its various forms. The latest example of electric lighting accessories, holders, cut-outs, &c., are shown, and also machines at work actually producing same. Another interesting exhibit is that of the Telautograph, which is demonstrated daily.

The central reception room contains some examples of the company's latest patterns in artistic electric fittings; electric fans of various types and electric radiators are also displayed. The company is also making an exhibit in this room of the latest applications of electricity as applied to medical science.

MESSRS. W. H. ALLEN & CO., LTD., BEDFORD.

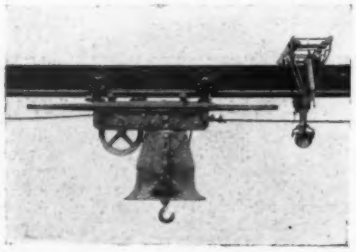
One of the most conspicuous stands devoted to exhibits of heavy machinery is that of the above company, whereon figured prominently a three-crank, three-cylinder compound enclosed engine. It is fitted throughout with a system of forced lubrication, and has one high pressure cylinder 16 ins. diameter and two low pressure cylinders 18 ins. diameter, with a common stroke of 10 ins. The engine,



TEMPERLEY TRANSPORTER.

which is designed primarily for dynamo driving in connection with electric lighting or transmission of power work, is capable of developing 440 b.h.-p. at 400 revolutions per minute, and is suitable for a steam pressure of from 100 to 200 lbs. per sq. in., condensing or non-condensing.

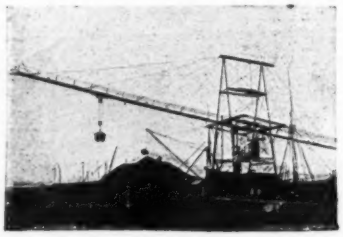
Another feature of this stand is a two-crank compound enclosed engine fitted with a system of forced lubrication and having cylinders 8 ins. and 15 ins. diameter by 7 ins. stroke, capable of developing 130 b.h.-p. at a speed of 500 revolutions per minute with a steam pressure of 100 to 200 lbs. per square inch, condensing or non-condensing. This engine is also for coupling to a dynamo for electric lighting or transmission of power work. Other exhibits include a 30 b.h.-p. single-crank single cylinder high-pressure enclosed engine capable of developing 30 b.h.-p. at 750 revolutions per minute with 100 to 200 lbs. steam pressure; a surface condenser having a tube surface of 1,000 sq. ft., capable of dealing with 10,000 lbs. of steam per hour, and a steam-driven twin air pump of the Allen-Edwards design suitable for dealing with the condensed water from the above condenser. Other exhibits consist of a three-throw electrically driven Allen-Edwards air pump capable of dealing with 25,000 lbs. of steam per hour when running at a speed of 160 revolutions per minute, for driving by an electric motor, and a crankshaft taken from one of the company's three-crank compound 600 b.h.-p. high-speed engines. This crankshaft has been running in the engine for seven years, working 12 hours a day and 300 days in the year and giving considerably more than the horse power for which it was designed at a speed of 300 revolutions per minute. After this long and arduous work the wear in many parts is so small that it is incapable of being measured and in all other places is merely microscopic.



TEMPERLEY PATENT TRAVELLER.

TEMPERLEY TRANSPORTER CO., 72, BISHOPSGATE STREET, WITHIN.

The stand of the above company forms a centre of attraction, the working models of distinctive types of transporters for unloading and loading vessels, railway trucks, &c., handling coal and other material illustrative of modern methods of saving labour proving of exceptional interest to most of the visitors. The exhibit comprises—(*a*) a fixed transporter fitted with a "Temperley" grab at an electrical generating station showing the company's latest method of handling coal or other material with



TEMPERLEY TRANSPORTER.

grabs; (*b*) a travelling Tower Transporter working a dumping skip, discharging coal from vessels on to stock heap or into railway waggons; (*c*) a portable transporter rigged on a vessel's derrick, for discharging cargo, worked by the vessel's own winch; (*d*) a "Temperley" patent traveller to lift and carry gross loads of 35 cwt. The exhibit first mentioned, namely, the fixed transporter with grab, calls for particular mention. It is shown discharging coal from the hold of a lighter direct into the storage hoppers over the boilers at a central station. The operating winches are of the latest design and are driven by electric motors. The operations of lifting, lowering, opening and closing the grab are performed by means of a double drum winch, and the traveller is traversed along the transporter beam by a separate winch. The hoisting winch is fitted with special compensating gear, enabling the operations of hoisting or lowering and transporting to be carried on singly or simultaneously, without one motion interfering with the other. This secures considerable saving of time, as the horizontal transporting motion can be commenced as soon

as the load is lifted high enough to clear the coamings of the vessel's hatchways, and before it is lifted to its full height, and the load or grab can be again lowered to the level at which it is to be discharged before the transporting movement is completed. The transporter is also shown working with an automatic dumping skip, which after being filled in the vessel's hold, is lifted and transported over the stock heap or hoppers and there automatically tipped.

The grab is of the two-rope type, and can be opened or closed in any position, and at any time the operator may wish. It can, therefore, be lowered through a hatchway while closed and then opened before being lowered on to the coal, allowing it to be worked close to the side of the hold, and avoiding damage to the hatchways, &c. These grabs are so designed and arranged that the quantity of material lifted is large in proportion to their weight. They are made with plain edges, so that they do not damage the floors of the vessels from which they are working. They can be made of a lifting capacity of from 12 cwt. to 5 tons or more, and according to the power of the motors and winches duties can be obtained of from 20 tons to upwards of 200 tons per hour with one transporter.

THE ELECTRIC AND ORDNANCE ACCESSORIES CO., LIMITED, STELLITE WORKS, BIRMINGHAM.

This firm are exhibiting a fairly comprehensive range of electrical appliances for all classes of work. Amongst other things, they are showing a model passenger lift consisting of complete motor and automatic control outfit, specially geared to very slow speed to enable the working of the controller to be seen. This model is shown in motion. A range of "Stellite" continuous current motors forms an important item, machines being exhibited from ¼ h.-p. to 15 h.-p., protected and totally enclosed types, also machines with worm reduction gear and back gear. Among the small size motors are machines for driving sewing machines, electric drilling, polishing, &c. Amongst the range of fans shown is the new A. P. type, which has found such great favour during this season. Fans are also shown of the pedestal, trunnion, porthole and ceiling types, all of British manufacture. The "Stellite" crane controllers also form an interesting item of this stand, those shown being of the tramway type, arranged for reversing, compound, and two voltage control, with or without braking points. No wood or fibre is used in their construction, and the contact fingers are all in separate insulated compartments, so that arcing is practically impossible. A powerful magnetic blowout is provided, and easy access can be obtained to all parts for inspection. The weight of the drum is taken by the ball thrust bearing. A new pattern of circuit breaker is just ready for the market, and is designed for use where a simple and cheap form of circuit breaker is required. Amongst the range of single and double automatic release motor starters and motor panels is the "Stellite" starter and speed regulator which places the control of the motor entirely out of the hands of the operator, and is claimed to be fool proof at all points. Slow movement starters in watertight and gastight cases are also shown. The improved "Stewart" enclosed arc lamps occupy an important position on this stand. These are British made throughout, and are constructed for single or series running, with double or single enclosure, for all voltages, direct current. A special pattern is one for which the makers claim high actinic power for photographic work. Telephones of many patterns are shown, and a switchboard of the "Stellite" central battery exchange system is shown in operation. It is claimed that this is an ideal system for large factories, business premises and public institutions. It has recently been installed in Osborne House, Isle of Wight; Somerset House, London; the University College, London, and in some of the very largest works in the country. Instruments for inter-communication without an intermediate switchboard are shown, together with special patterns for stenographers, mining (watertight), &c. The "Stellite" S. D. telephones for reply and call, and single call systems are shown, some in operation. These telephones are arranged to attach to existing electric bells, and are primarily intended for domestic purposes. They are of British make throughout, and are very substantially constructed, a feature which is often lacking in the type of telephone sold for similar purposes. One of the important claims for consideration that this stand possesses is that all goods shown are of British manufacture.

STEWARTS AND LLOYDS, LTD., COATBRIDGE.

This firm show a representative exhibit of their manufactures, restricting it, however, to their various specialities pertaining to electrical installations and equipment generally. The principal exhibits consist of electric tramway poles of both tapered and three-section make, the former 31 ft. long and tapered uniformly from end to end in one piece, and the latter of parallel lapwelded tubes shrunk together and of a similar over-all length with pole mountings representing the latest practice in span wire, and in side arm and double arm poles both with bent and straight arms. They also show fine examples of lapwelded steel steam mains fitted with their well-known welded-on flanges. These flanges were introduced by the exhibitors some fifteen years ago and have proved so satisfactory that they have practically become the general practice for steam pipe installations. They exhibit a good sample of forged steel sliding expansion piece of lapwelded steel tube throughout with forged flanges welded

on, and show samples of bent steel steam pipes which they make in all sizes up to 20 in. bore. They also display interesting samples of long tubular steel derricks 33 ft. long in one piece having their maximum diameter in the centre and tapered uniformly to both ends, thus giving the required strength with the minimum of weight. Their exhibits also include a good sample of their patent Mephan Ferguson Lock Bar Pipe, which they make in all sizes from 18 ins. to 72 ins. diameter. This is the pipe which, in the first instance, made itself famous in Australia, where it has been adopted with such conspicuous success for the 30 ins. Coolgardie Water Main three hundred and eighty miles long and also for the Adelaide, Melbourne and Sydney and other Colonial water supplies. These pipes have recently been applied to power gas mains, and are now coming strongly into favour, not only for water and sewage pipes at moderate pressures, but for high pressure electrical generating power mains, where their enormous strength compared with pipes of any other make promises a great future for them, particularly in view of the great developments all over the world in hydro-electric installations, in many of which long pipe lines are required from 30 ins. to 60 ins. diameter, and for pressures exceeding 500 lbs. per sq. in., and for which their pipes are pre-eminently suited. The large and varied nature of this company's exhibit renders it a conspicuous object in the exhibition, and it should prove highly instructive to electrical experts and others.

MESSRS. CROMPTON

show on their stand examples of all their smaller manufactures, prominent among which is a 30 h.-p. single-phase motor, driving a dynamo supplying the continuous current to several of the motors and arc lamps on the stand. The motor runs at about 750 revolutions per minute, and can be recoupled to work on a three-phase circuit, giving 50 h.-p. at the same speed.

There is also a single-phase lift motor of the reactance type, designed to start against heavy loads with a low-starting current.

A range of continuous current motors are shown, some of them in actual operation. Attention is drawn to the several types of speed-reducing gear, which have been specially designed.

To central station engineers that portion of the stand devoted to auxiliary machinery will probably be of particular interest. In this portion of the stand are shown two-feed pumps of novel design and a motor-driven air pump, all of which deserve special consideration. Ceiling fans form a feature of the stand, as does also a fine display of continuous current flame arc lamps. The main portion of the exhibit is lighted by enclosed and open lamps of different types. The Midget lamps, which are of an improved pattern, burning for about seventy to eighty hours, deserve particular attention. Also several other types of arc lamps and accessories, the fittings especially designed for street-lighting pillars being of particular interest. A 20 in. projector and some of Messrs. Crompton's special projector lamps are also shown on this portion of the stand.

The switch gear exhibit includes a very fine switch board, suitable for controlling a private plant, and also several examples of the heavy current switch gear manufactured by the firm. Amongst other apparatus, we notice the Crompton-Barton Automatic Circuit-Breaker, which possesses several novel features.

Instruments of various patterns are exhibited on the switch panels mentioned above, and in addition a portion of the stand is devoted to instruments of the higher grade, suitable for testing laboratories, technical schools, &c.

The central exhibit represents a testing table, one end being arranged for potentiometer measurements of all descriptions, the other end being arranged for resistance measurements.

In addition, several pyrometers, standard resistances, and other instruments of this description are shown.

MESSRS. BABCOCK AND WILCOX, LTD.,

have installed one of their well-known marine type boilers in the yard, which is generating steam for the exhibition. It has 2,218 sq. ft. of heating surface, and is fitted with a feed water heater and mechanical chain grate stoker. In the exhibition itself, the company show a variety of their steam raising apparatus, including models of a water-tube boiler, mechanical chain grate stoker for burning low-grade fuels; Gutmann's water softening and purifying plant; turbine tube cleaner for removing incrustation from boiler or economiser tubes; specimens of wrought-steel steam piping.

That portion of the exhibit to which attention is naturally drawn consists of an electrically driven silent gravity bucket conveyor for dealing with coal, coke, ashes, &c.

This apparatus is made up of a special compensating pawl driver, with direct-geared electric motor; double chain length of conveyor with special hydraulically stamped seamless buckets; steel frame; fixed automatic continuous filler for supplying buckets with material without spilling. This conveyor has many outstanding features of excellence, in particular the driving device, and in the application of free or revolving curves where the direction of the conveyor is changed. In descending from an upper run to any depth the maximum stress is at the point of turning to descend, and here the wheels carrying the chain and buckets cease to rotate as soon as they touch the revolving free wheels.

An approximate idea of the cost of handling by this conveyor may be formed when we state that in conveying and lifting forty tons per hour to a height of forty feet, ten hours per day, by a conveyor costing £1,000, allowing for

interest on capital expenditure, attendance, oil, motive power, depreciation, and repairs, the cost works out at less than ¼d. per ton.

MESSRS. McPHAIL AND SIMPSON

are, as is generally known, chiefly concerned with superheating, and their stall contains an interesting collection of apparatus and parts relating to this all-important branch of economical steam raising. There are noticeable a superheater of dished box header type; a high temperature superheater; tube plate 1¾ ins. thick with cold solid drawn steel superheater tubes expanded and beaded over, also wrought steel dished headers, one with stand-pipe holes cut out, the other with weldless steel stand-pipes riveted on. The latter has thermometer mercury pockets and a dead weight safety valve. Other varieties of headers are shown both finished and in the rough as they pass from the machine. One of the most interesting features of the stand, however, consists of specimens of superheated tubes which have been at work continuously night and day for ten years in a Babcock and Wilcox water tube boiler, and which have been cut out for exhibiting. They are from the first superheater made for a water tube boiler of any type, and were by McPhail and Simpsons, Limited. They are quite sound, and not in the least deteriorated from the long use in the exceedingly high temperature, the steam passing from them being over 700° F.

MESSRS. JOSEPH RHODES & SONS'

stand contains machinery exhibits of interest to manufacturers of electrical machinery. Foremost is an old friend in the shape of the No. 6 power press, particularly adapted for cutting out stampings for armature discs, a neighbouring machine being the No. 20 adjustable power press suitable for stamping out switch covers and other small electrical stampings. Also to be noted is a high-speed shearing machine, suitable for cutting sheets 3 ft. wide by 14 B.W.G. thick, at a speed of 100 cuts per minute.

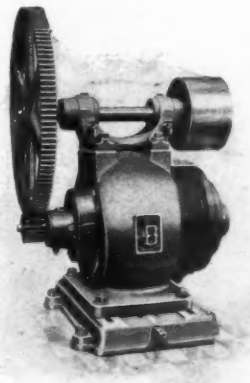
All these machines are fitted with "Rhodes" patent safety clutch motion, which enables them to be run at very high speeds.

ELECTROMOTORS, LIMITED,

of Openshaw, Manchester, have a fine exhibit of highly specialised electrical machinery which includes a range of continuous current motors from ¼ to 25 B.H.-P., occupying a large portion of the stand. They are manufactured on an absolutely interchangeable system and embody every improvement that is possible, and the details are well worthy of examination, both for variety and ingenuity. They are also representative of the variable speed motors manufactured by the company, and also of the crane motors, except that, in this case, the shafts are stronger, although the general design is the same.

An example of spur reduction gear is shown, with a reduction ratio of about 5 to 1. The salient features are raw-hide shrouded pinion and machine-cut wheel and self-lubricating bronze-lined bearings.

There is also displayed a worm-geared motor consisting of a standard 3½ B.H.-P. motor, combined on one bedplate, with a silent worm reduction gear, having a ratio of 10 to 1. It has a solid worm with ball thrust bearings and bronze wheel, thus making a neat, efficient, and silent reduction gear. Three sizes of propeller ventilating fans are shown. They are all of



ELECTROMOTORS, LTD.: MOTOR WITH SPUR REDUCTION GEAR.

the slow speed type, with totally enclosed motors. The largest (30 in.) is capable of dealing with 6,500 cublic feet of air per minute, with a current consumption of but 300 watts at a speed of 420.

The automatic system controlling the exhibit at this stand affords a striking example of what can be achieved by present day standard apparatus. Although we cannot at the moment point to the practical utility of this ingenious example of controlling,* it must be admitted in this case it has fully achieved its object, which was to attract visitors to the stand. Briefly the arrangement is as follows: The switchboard contains twelve solenoid main switches and four solenoid controlled starting switches. Twelve solenoid main switches are brought into operation in turn by means of a motor-driven "master drum." The latter is driven through worm gear and ratchet wheel,

* See however p. 346. Such an apparatus would probably apply to the arrangement of power doors therein described.

and turns through a revolution in about six minutes. Twelve studs corresponding with the twelve solenoid switches are fixed to the disc of the drum, and are brought into contact with a flipper in turn. This completes the circuit of the solenoid switch, which at once closes and selects a piece of apparatus. Immediately this switch closes the solenoid of the starting switch selected is excited and the motor starts. The continuous forward movement of the drum disc in about thirty seconds opens the circuit of the solenoid main switch, which of course stops the motor; immediately the next stud comes in contact with the flipper, and the same cycle of operation is repeated with another starting switch and another piece of apparatus. And so on through the twelve motors.

Another speciality, of considerable use in hotels, clubs, &c., is the boot polisher exhibited. It consists of two rotating brushes, one of which is coarse and the other fine, for polishing.

A model service lift is shown. It is of the push-button type, made by the well-known firm of Messrs. J. G. Childs & Co., Ltd., Willesden Green, London, and consists of a balanced cage, operated by a specially designed motor. Each floor is provided with three pushes, to raise, stop and lower the cage, and thus control the hoist in as simple manner as it is possible to do so.

The solenoids and self-starting switches, mounted on the switchboard and operating in connection with the exhibit, are manufactured by Messrs. Sturtevant Engineering Co., Ltd. The instruments are of Messrs. Elliott Bros.' make.

CONSOLIDATED PNEUMATIC TOOL CO.

This exhibit comprises a selection of portable electric tools suitable for drilling holes from $\frac{3}{8}$ in. to $2\frac{1}{2}$ in. in mild steel. The outstanding features of these drills are their lightness and efficiency. The $\frac{3}{8}$ in. drill, which is a breast drill and can be operated from any electric lamp socket, weighs only 12 lbs., and is wound for any voltage up to and including 250 volts, which is the case with all the drills: 500-volt drills have not yet been made, as this company do not consider it desirable on account of the risk which the operator runs when handling such high voltages, though they are experimenting with a new type of drill by means of which they hope it will be possible to eliminate much of the risk which has hitherto appertained to high voltages. The remarkable efficiency of these drills is obvious from the fact that they can drill 500 $\frac{1}{2}$ in. holes through 1 in. mild steel plate with one pennyworth of electricity.

This firm is making a speciality of drill posts with magnets in the base of the pillar, so that when using these drills on flat steel or iron surfaces, such as, for instance, drilling ship plates, the floors or sides of steel wagons, girders for bridges, &c., all that is necessary is to move the drill post into position and turn the switch, and the magnet holds the drill firmly to the work. Moreover, as the arm of the drill can be raised or lowered and also swing round-about, it is obvious that such a tool has all the advantages of a radial drill, while at the same time it is portable and requires no time to fix.

Portable emery grinders are also made by this company, as well as bench emery wheels, one of which is shown in operation at their stand. It has, in addition to the usual starting gear, an overload device which opens the circuit the moment the motor is overloaded. This precludes the possibility of the workmen damaging the machine.

As practically all the tools can be seen in operation, a visit to the stand will prove of considerable interest to the engineer.

MESSRS. COWANS', LTD.,

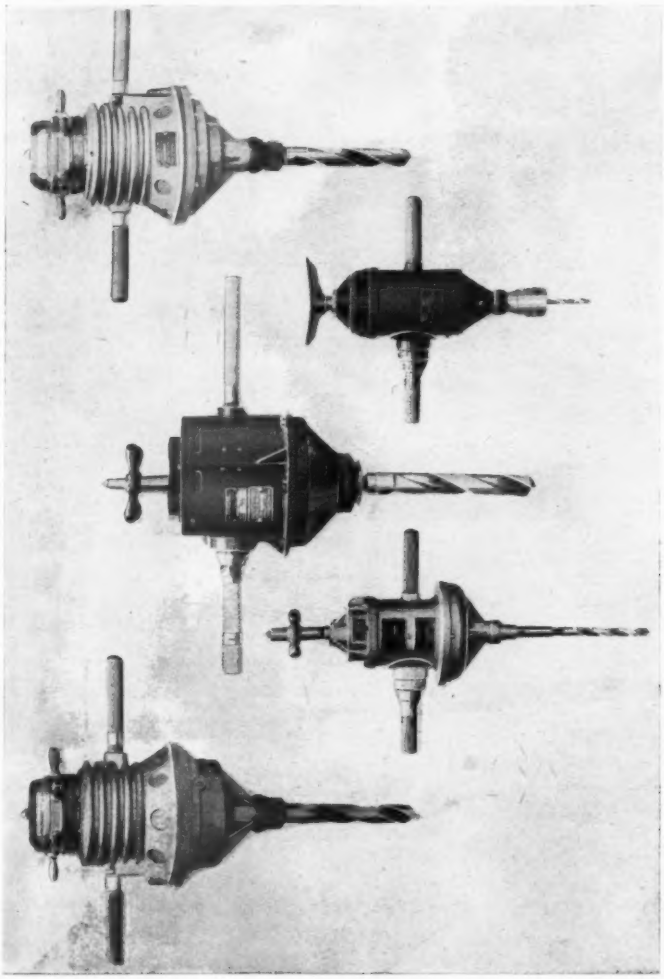
exhibit includes a novelty in the shape of a circuit breaker, as supplied for His Majesty's new battleships.

One-thousand ampere and 500-ampere instruments are shown of the type made to the specification of the Admiralty for the battleships "Hibernia," "Britannia," "Africa," and "Warrior." They are double pole tandem pattern, with overload release combined with time element in both poles and reverse current release of the "Andrews" type in one pole. The circuit breakers are fitted with magnetic blow-out of moderate strength, in accordance with this firm's standard practice The magnetic blow-out being combined with a wide spring break, the strong magnetic field usually adopted is not necessary, as, with all moderate currents, the circuit is opened safely, without the assistance of the magnetic field. The result of this arrangement is that the breakers do not rupture the circuits with explosive violence with the consequent rise of pressure in the circuit of any appreciable inductance. The breakers are fitted with a free operation handle, so that they are free to open the circuit when the handle is grasped by the attendant. The "Andrews" reverse current release acts directly on the tripping gear, without the intervention of any relay. This release gear is guaranteed to open the circuit breaker with a reverse current, though the pressure of the current fall to 25 per cent. of the normal.

MESSRS. FRICKER AND MILLER.

On this stall are displayed several novelties shown for the first time, consisting of a remote control switch, thermal volt and ampere meters, and the Mordey-Fricker electrolytic repayment meter. The remote control switch is an apparatus designed to be operated by a momentary fall in pressure, and to be used on consumers' services in connection with two-rate meters, demand indicators, &c. It

comprises a wound-up clock train with an escapement. The pallet lever is held over by an electro-magnet against the force of a light helical spring. This electro-magnet is normally energised across the supply mains and is wound with very fine wire, and absorbs about one watt. If the pressure is momentarily interrupted or greatly reduced the magnet lets go and the spring rocks the pallet lever back, the magnet immediately recovering and pulling it again into the normal position. Thus one tooth of the escapement is slipped at each momentary drop in the pressure. A cam on the escapement shaft transforms these angular movements of the shaft to alternate up and down movements of a light balance rod carrying short-circuiting forks at the ends, dipping in and out of mercury cups. The apparatus would be operated twice in the 24 hours, and a single winding of the mechanism would last for some



CONSOLIDATED PNEUMATIC TOOL CO., LTD.: GROUP OF ELECTRIC DRILLS.

thirty years at the slow rate of release; consequently the question of re-winding need not be considered.

In the thermal volt and ampere meters a differential air thermometer is immersed in water, and the air in one bulb is heated by an internal resistance wound over a slip of thin mica and connected to platinum wires which are sealed into the glass. The water bath acts as a temperature equaliser, so that changes in the comparative thermal conditions of the two bulbs are rapidly indexed by the column of liquid in the connecting tube.

Differential thermometers heated by conductors placed round or near one of the bulbs have been suggested as ampere-meters and voltmeters by Professor Perry and others, but the sluggishness of the indications of such instruments in air as the surrounding medium is so great as to render them valueless. By keeping the bulbs in intimate contact with a medium having a great heat capacity like water, this sluggishness is remarkably reduced, and the rate at which changes are indexed becomes quite rapid enough for practical utility.

The instrument is accurate, and is not liable to changes in the zero, nor does it absorb anything like so much energy as hot wire instruments, being in fact about twenty times more sensitive. For example, in Cardew's voltmeter measuring 120 volts 47 watts were absorbed in the instrument, or nearly ·4 watt per volt. In the hot air instrument the resistance in a meter reading 200 volts is 10,000 ohms, giving 4 watts for a full scale reading, or ·02 watt per volt. The pattern for these instruments it may be mentioned is not yet standardised.

The electrolytic prepayment meter comprises a depositing cell wherein the cathode is fixed and partitioned off from the anode by a perforated celluloid diaphragm. The anode is in the form of a roll of thin copper strip carried on the upper part of the plate covering the cell. A definite length of this strip, which is rolled to a uniform thickness, is fed into the electrolyte over a spocket roller through a slot in the cover plate by the operation of each coin. When the portion thus immersed has all been dissolved by electrolysis and a like quantity deposited on the cathode, the circuit is automatically broken at the surface of the electrolyte.

The average drop depends on the length of anode immersed, and, with one coin's worth only, does not exceed 1·3 volts per ampere passed.

The anode rolls are made to serve for 600 coins, and, together with the cathode plates, are readily renewed. The difference between the value of the copper in the rolled anode form and as deposited on the cathode is about 1 per cent. of the revenue from the meter.

The electrolyte consists of copper nitrate, and is unaltered by the action of the current, Copper nitrate being a deliquescent salt, there is no evaporation of water, and consequently no "creeping" of the salt itself.

A counter records continuously the number of coins paid in, this record multiplied by a constant giving the units consumed.